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VEHICLE EXHAUST EMISSION INSTRUMENTS EVALUATION

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

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Government agencies have become involved in vehicle maintenance through the initiation of periodic vehicle emission inspection requirements carried out at State or local levels. The key element in all vehicle engine maintenance, inspection and emission detection is the exhaust emission analyzer. Exhaust emission analyzers are presently available in many different designs, covering a broad price range and offering various capabilities and features. The objective of this study was to survey the market and identify all exhaust emission analyzer manufacturers, whose product could be used in vehicle inspection/maintenance (I/M) programs. Consequently, a representative group of instruments was selected and a series of tests were conducted to evaluate instrument performance.

Major findings of this program:

1. A significant number of HC/CO I/M emission analyzers are presently available.
2. The vast majority of HC/CO instruments use an infrared absorption operating principle.
3. The hydrocarbon response characteristics of the HC/CO instruments generally showed greatest sensitivity to isobutylene, followed by toluene, methane, and ethylene. The units demonstrate essentially no sensitivity to acetylene and benzene.

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Page 7-83: Change the manufacturer from Kal Equip to Stewart Warner.

Page 7-262: Change IBC N322 N/SC-400 to IBC N322 W/SC-400.

General Comment: The terms of Contract No. 68-03-2353 do not provide for repairs to be performed by the contractor on the failed instruments, which are the property of EPA.

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VEHICLE EXHAUST EMISSION INSTRUMENTS EVALUATION

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FOREWORD

Periodic motor vehicle exhaust emissions inspection and maintenance has shown itself to be an effective tool to minimize the contribution of vehicle exhaust emission to total air pollution.

Proper engine tune-up and operation is vitally important in the fight against air pollution. In addition to tune-up, vehicle inspection and excessive exhaust emission detection are necessary for a continuing program of emission control.

Individual vehicle owners have a responsibility to maintain their vehicles in optimum condition to minimize emissions. Government agencies have recently become involved in vehicle maintenance through the initiation of periodic vehicle emission inspection requirements carried out at state or local levels.

The key element in all vehicle engine maintenance, inspection and emission detection is the exhaust emission analyzer. Exhaust emission analyzers are presently available in many different designs, offering various detection capabilities over a broad price range. The objective of this study is to survey the market and identify all exhaust emission analyzer manufacturers whose product could be used in vehicle inspection/maintenance (I/M) programs. A representative group of instruments was selected and a series of tests were conducted to evaluate instrument performance.

ABSTRACT

Government agencies have become involved in vehicle maintenance through the initiation of periodic vehicle emission inspection requirements carried out at State or local levels. The key element in all vehicle engine maintenance inspection and emission detection is the exhaust emission analyzer. Exhaust emission analyzers are presently available in many different designs, covering a broad price range and offering various capabilities and features. The objective of this study was to survey the market and identify all exhaust emission analyzer manufacturers, whose product could be used in vehicle inspection/maintenance (I/M) programs. Consequently, a representative group of instruments was selected and a series of tests were conducted to evaluate instrument performance.

Major findings of this program:

1. A significant number of HC/CO I/M emission analyzers are presently available.

2. The vast majority of HC/CO instruments use an infrared absorption operating principle.

3. The hydrocarbon response characteristics of the HC/CO instruments generally showed greatest sensitivity to isobutylene, followed by toluene, methane, and ethylene. The units demonstrate essentially no sensitivity to acetylene and benzene.

CONTENTS

Page

Foreword iii
Abstract iv
Figures vii
Tables ix

1 INTRODUCTION 1-1
1.1 Major Findings 1-2
1.2 State of the Art 1-3

2 INSTRUMENT SURVEY, SELECTION, AND PROCUREMENT 2-1
2.1 Information Sources 2-1
2.2 Selection Criteria 2-9
2.3 Survey Results 2-9
2.4 Selected Instruments 2-18

3 LABORATORY TESTS 3-1
3.1 Instrument Warm Up 3-3
3.2 Instrument Calibration 3-3
3.3 Instrument Zero Drift 3-3
3.4 Instrument Gas Interference 3-5
3.5 Instrument Accuracy Determination 3-5
3.6 Response and Recovery 3-5
3.7 Voltage Variation 3-6
3.8 Hydrocarbon Response 3-6
3.9 Repeatability Tests 3-6
3.10 Facilities 3-7

4 VEHICLE TESTS 4-1
4.1 Instrument Warm Up 4-1
4.2 Instrument Calibration 4-1
4.3 Loaded Steady-State 4-1
4.4 Lean Loaded Steady-State 4-1
4.5 Calibration Check 4-4
4.6 Instrument Hang-Up 4-4
4.7 Rich Loaded Steady-State 4-4
4.8 Instrument Recalibration 4-4
4.9 Diagnostic Emission Measurements 4-4
4.10 EPA Analysis Bench and Calibration Gases 4-5
4.11 EPA Instrument Calibration 4-5

5 DURABILITY TESTS 5-1
5.1 Scope 5-1
5.2 Service 5-1
5.3 Instrument Failure 5-1
5.4 Vibration and Shock Tests 5-4

CONTENTS (CONT'D)

Page

5.5 Data. 5-6
5.6 Exposure Rating 5-6
5.7 Service Data. 5-6
5.8 Durability Span Drift 5-6

6 GENERALIZED DATA PRESENTATION AND RATINGS 6-1
6.1 Observed Performance Data 6-1
6.2 Objective Ratings 6-1

7 INDIVIDUAL INSTRUMENT REPORTS 7-1
7.1 Horiba Mexa 300A Infrared Exhaust Analyzer. 7-1
7.2 Barnes 8335C Emission Analyzer. 7-17
7.3 Scott IIIC Exhaust Emission Analyzer. 7-34
7.4 Marquette 42-160 Infrared Emissions Analyzer. 7-51
7.5 Beckman 590 HC/CO Tester. 7-67
7.6 Stewart Warner 3161 Infrared Gas Analyzer 7-83
7.7 Sun EPA 75 Exhaust Performance Analyzer 7-100
7.8 Mopar IIIC Exhaust Emission Analyzer. 7-116
7.9 Sears 713.21022 HC-CO Analyzer. 7-133
7.10 Kal Equip 4094-D Infrared Emissions Analyzer. 7-148
7.11 Pulsar 662 Infrared Analyzer. 7-164
7.12 Autoscan 710C HC/CO Analyzer. 7-180
7.13 Allen 23-160 CA CO/CH Infrared Exhaust Emission Analyzer. . 7-196
7.14 Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer. 7-213
7.15 Horiba Mexa 240 Infrared Analyzer 7-231
7.16 Thermo Electron 8A NO Analyzer. 7-247
7.17 IBC N322 W/SC-400 Nitrogen Oxide Analyzer 7-262

FIGURES

Number Page

3-1 Laboratory Test Sequence. 3-2
3-2 Sample Warm-up Time Plot. 3-4
3-3 Repeatability Test. 3-8
3-4 Environmental Chamber 3-9
3-5 Environmental Chamber with Calibration Gases. 3-10
3-6 Environmental Chamber, Interior 3-11
3-7 Instruments Inside Environmental Chamber. 3-12
3-8 Olson Laboratories, Inc., High Altitude Test Facility - Big Bear Lake, California 3-13

4-1 Vehicle Test Sequence 4-2
4-2 EPA Analytical System 4-6
4-3 Vehicle Test Setup. 4-7
4-4 Common Sampling Manifold. 4-8

5-1 Durability Test Setup 5-2
5-2 Vehicle Test in Progress. 5-3
5-3 Vibration Test Platform 5-5

7-1 Horiba Mexa 300A Infrared Exhaust Analyzer. 7-14
7-2 Horiba Mexa 300A Infrared Exhaust Analyzer (Back) 7-15
7-3 Horiba Mexa 300A Infrared Exhaust Analyzer (Left Side). . . 7-16
7-4 Barnes 8335C Emission Analyzer. 7-30
7-5 Barnes 8335C Emission Analyzer (Back) 7-31
7-6 Barnes 8335C Emission Analyzer (Left Side). 7-32
7-7 Barnes 8335C Emission Analyzer (Right Side and Probe) . . . 7-33
7-8 Scott IIIC Exhaust Emission Analyzer. 7-48
7-9 Scott IIIC Exhaust Emission Analyzer (Back) 7-49
7-10 Scott IIIC Exhaust Emission Analyzer (Left Side and Probe). 7-50
7-11 Marquette 42-160 Infrared Emissions Analyzer. 7-64
7-12 Marquette 42-160 Infrared Emissions Analyzer (Left Side). . 7-65
7-13 Marquette 42-160 Infrared Emissions Analyzer (Back) 7-66
7-14 Beckman 590 HC/CO Tester. 7-80
7-15 Beckman 590 HC/CO Tester (Back) 7-81
7-16 Beckman 590 HC/CO Tester (Left Side). 7-82
7-17 Stewart Warner 3161 Infrared Gas Analyzer 7-97
7-18 Stewart Warner 3161 Infrared Gas Analyzer (Back). 7-98
7-19 Stewart Warner 3161 Infrared Gas Analyzer (Right Side). . . 7-99
7-20 Sun EPA 75 Exhaust Performance Analyzer 7-113
7-21 Sun EPA 75 Exhaust Performance Analyzer (Back). 7-114
7-22 Sun EPA 75 Exhaust Performance Analyzer (Right Side and Probe). 7-115
7-23 Mopar IIIC Exhaust Emission Analyzer. 7-130
7-24 Mopar IIIC Exhaust Emission Analyzer (Back) 7-131

FIGURES (CONT'D)

Number | Page

7-25 Mopar IIIC Exhaust Emission Analyzer (Left Side and Probe). 7-132
7-26 Sears 713.21022 HC-CO Analyzer. 7-145
7-27 Sears 713.21022 HC-CO Analyzer (Back and Probe) 7-146
7-28 Sears 713-21022 HC-CO Analyzer (Right Side and Probe) . . . 7-147
7-29 Kal Equip 4094-D Infrared Emissions Analyzer. 7-161
7-30 Kal Equip 4094-D Infrared Emissions Analyzer (Back and Probe). 7-162
7-31 Kal Equip 4094-D Infrared Emissions Analyzer (Left Side). . 7-163
7-32 Pulsar 662 Infrared Analyzer. 7-177
7-33 Pulsar 662 Infrared Analyzer (Back) 7-178
7-34 Pulsar 662 Infrared Analyzer (Left Side and Probe). 7-179
7-35 Autoscan 710C HC/CO Analyzer. 7-193
7-36 Autoscan 710C HC/CO Analyzer (Back) 7-194
7-37 Autoscan 710C HC/CO Analyzer (Right Side, Probe, and Span Gas Container) 7-195
7-38 Allen 23-160 CA CO/HC Infrared Exhaust Emission Analyzer. . 7-209
7-39 Allen 23-160 CA CO/HC Infrared Exhaust Emission Analyzer (Back). 7-210
7-40 Allen 23-160 CA CO/HC Infrared Exhaust Emission Analyzer (Right Side). 7-211
7-41 Allen 23-160 CA CO/HC Infrared Exhaust Emission Analyzer (Probe) 7-212
7-42 Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer (Front). 7-227
7-43 Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer (Back) 7-228
7-44 Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer (Right Side) 7-229
7-45 Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer (Control Unit) 7-230
7-46 Horiba Mexa 240 Infrared Analyzer 7-244
7-47 Horiba Mexa 240 Infrared Analyzer (Back). 7-245
7-48 Horiba Mexa 240 Infrared Analyzer (Left Side and Probe) . . 7-246
7-49 Thermo Electron 8A NO Analyzer. 7-259
7-50 Thermo Electron 8A NO Analyzer (Back) 7-260
7-51 Thermo Electron 8A NO Analyzer (Right Side and Probe) . . . 7-261
7-52 IBC N322 W/SC-400 Nitrogen Oxide Analyzer 7-275
7-53 IBC N322 W/SC-400 Nitrogen Oxide Analyzer (Back). 7-276
7-54 IBC N322 W/SC-400 Nitrogen Oxide Analyzer (Left Side) . . . 7-277
7-55 IBC N322 W/SC-400 Nitrogen Oxide Analyzer - Sampler Control Module. 7-278
7-56 IBC N322 W/SC-400 Nitrogen Oxide Analyzer - Sampler Control Module (Back and Probe) 7-279
7-57 IBC N322 W/SC-400 Nitrogen Oxide Analyzer - Sampler Control Module (Right Side and Probe) 7-280

TABLES

Number Page

2-1 List of State and Local Government Agencies 2-3
2-2 List of Prospective Manufacturers, Assemblers or Distributors. 2-6
2-3 Prospective Instruments with Manufacturer Cross Index . . . 2-10
2-4 Advertised Performance Specifications 2-16

4-1 Loaded Steady-State Horsepower Values for Loaded Vehicle Test. 4-3

6-1 Observed Performance Data Table 6-2
6-2 Warmup Time: (Temperature and Humidity - Quickest Warmup Time to Slowest) 6-3
6-3 Zero Drift (Temperature and Humidity) 6-4
6-4 Accuracy Determination (Temperature and Humidity) - (Most Accurate to Least Accurate) - Overall Accuracy Rating . . 6-5
6-5 Accuracy Determination (Temperature and Humidity) - (Most Accurate to Least Accurate) - High Range NO 6-6
6-6 Accuracy Determination - High Altitude. 6-7
6-7 Response and Recovery (Temperature and Humidity Cycles) - (Quickest to Slowest) 6-8
6-8 Gas Interference Laboratory Tests (Least Response to Most Response). 6-9
6-9 Voltage Profile (Least Influenced to Most Influenced) . . . 6-10
6-10 Vehicle Tests Accuracy (Most Accurate to Least Accurate) (Overall Accuracy Rating) 6-11
6-11 Vehicle Tests Accuracy (Most Accurate to Least Accurate) (Standard Mode) 6-12
6-12 Diagnostic Vehicle Tests (Most Accurate to Least Accurate) - (HC and CO) 6-13
6-13 Diagnostic Vehicle Tests (Most Accurate to Least Accurate) - (NO). 6-14
6-14 Durability Tests. 6-15
6-15 Instrument Service Requirements 6-16
6-16 Durability Tests (Life, Span Drift, Service and Shock Failure Parameters) 6-17

7-1 Horiba Mexa 300A Data Composite - Laboratory Test 7-5
7-2 Horiba Mexa 300A Data Composite - Repeatability Test. . . . 7-8
7-3 Horiba Mexa 300A Vehicle Test Accuracy Determination - Exhaust Gas 7-10
7-4 Horiba Mexa 300A Diagnostic Test. 7-12
7-5 Horiba Mexa 300A Durability Test Data 7-13
7-6 Barnes 8335C Data Composite - Laboratory Test 7-21
7-7 Barnes 8335C Data Composite - Repeatability Test. 7-24
7-8 Barnes 8335C Vehicle Test Accuracy Determination - Exhaust Gas 7-26

TABLES (CONT'D)

Number Page

7-9 Barnes 8335C Diagnostic Test 7-28
7-10 Barnes 8335C Durability Test Data 7-29
7-11 Scott IIIC Data Composite - Laboratory Test 7-39
7-12 Scott IIIC Data Composite - Repeatability Test 7-42
7-13 Scott IIIC Vehicle Test Accuracy Determination - Exhaust Gas 7-44
7-14 Scott IIIC Diagnostic Test 7-46
7-15 Scott IIIC Durability Test Data 7-47
7-16 Marquette 42-160 Data Composite - Laboratory Test 7-55
7-17 Marquette 42-160 Data Composite - Repeatability Test 7-58
7-18 Marquette 42-160 Vehicle Test Accuracy Determination - Exhaust Gas 7-60
7-19 Marquette 42-160 Diagnostic Test 7-62
7-20 Marquette 42-160 Durability Test Data 7-63
7-21 Beckman 590 Data Composite - Laboratory Test 7-71
7-22 Beckman 590 Data Composite - Repeatability Test 7-74
7-23 Beckman 590 Vehicle Test Accuracy Determination - Exhaust Gas 7-76
7-24 Beckman 590 Diagnostic Test 7-78
7-25 Beckman 590 Durability Test Data 7-79
7-26 Stewart Warner 3161 Data Composite - Laboratory Test 7-88
7-27 Stewart Warner 3161 Data Composite - Repeatability Test 7-91
7-28 Stewart Warner 3161 Vehicle Test Accuracy Determination - Exhaust Gas 7-93
7-29 Stewart Warner 3161 Diagnostic Test 7-95
7-30 Stewart Warner 3161 Durability Test Data 7-96
7-31 Sun EPA 75 Data Composite - Laboratory Test 7-104
7-32 Sun EPA 75 Data Composite - Repeatability Test 7-107
7-33 Sun EPA 75 Vehicle Test Accuracy Determination - Exhaust Gas 7-109
7-34 Sun EPA 75 Diagnostic Test 7-111
7-35 Sun EPA 75 Durability Test Data 7-112
7-36 Mopar IIIC Data Composite - Laboratory Test 7-121
7-37 Mopar IIIC Data Composite - Repeatability Test 7-124
7-38 Mopar IIIC Vehicle Test Accuracy Determination - Exhaust Gas 7-126
7-39 Mopar IIIC Diagnostic Test 7-128
7-40 Mopar IIIC Durability Test Data 7-129
7-41 Sears 713.21022 Data Composite - Laboratory Test 7-136
7-42 Sears 713.21022 Data Composite - Repeatability Test 7-139
7-43 Sears 713.21022 Vehicle Test Accuracy Determination - Exhaust Gas 7-141
7-44 Sears 713.21022 Diagnostic Test 7-143
7-45 Sears 713.21022 Durability Test Data 7-144

TABLES (CONT'D)

Number Page

7-46 Kal Equip 4094-D Data Composite - Laboratory Test 7-152
7-47 Kal Equip 4094-D Data Composite - Repeatability Test. . . . 7-155
7-48 Kal Equip 4094-D Vehicle Test Accuracy Determination - Exhaust Gas 7-157
7-49 Kal Equip 4094-D Diagnostic Test. 7-159
7-50 Kal Equip 4094-D Durability Test Data 7-160
7-51 Pulsar 662 Data Composite - Laboratory Test 7-168
7-52 Pulsar 662 Data Composite - Repeatability Test. 7-171
7-53 Pulsar 662 Vehicle Test Accuracy Determination - Exhaust Gas 7-173
7-54 Pulsar 662 Diagnostic Test. 7-175
7-55 Pulsar 662 Durability Test Data 7-176
7-56 Autoscan 710C Data Composite - Laboratory Test. 7-184
7-57 Autoscan 710C Data Composite - Repeatability Test 7-187
7-58 Autoscan 710C Vehicle Test Accuracy Determination - Exhaust Gas 7-189
7-59 Autoscan 710C Diagnostic Test 7-191
7-60 Autoscan 710C Durability Test Data. 7-192
7-61 Allen 23-160CA Data Composite - Laboratory Test 7-200
7-62 Allen 23-160CA Data Composite - Repeatability Test. 7-203
7-63 Allen 23-160CA Vehicle Test Accuracy Determination - Exhaust Gas 7-205
7-64 Allen 23-160CA Diagnostic Test. 7-207
7-65 Allen 23-160CA Durability Test Data 7-208
7-66 Autosense 200 Data Composite - Laboratory Test. 7-218
7-67 Autosense 200 Data Composite - Repeatability Test 7-221
7-68 Autosense 200 Vehicle Test Accuracy Determination - Exhaust Gas 7-223
7-69 Autosense 200 Diagnostic Test 7-225
7-70 Autosense 200 Durability Test Data. 7-226
7-71 Horiba Mexa 240 Data Composite - Laboratory Test. 7-235
7-72 Horiba Mexa 240 Data Composite - Repeatability Test 7-238
7-73 Horiba Mexa 240 Vehicle Test Accuracy Determination - Exhaust Gas 7-240
7-74 Horiba Mexa 240 Diagnostic Test 7-242
7-75 Horiba Mexa 240 Durability Test Data. 7-243
7-76 Thermo Electron 8A Data Composite - Laboratory Test 7-250
7-77 Thermo Electron 8A Data Composite - Repeatability Test. . . 7-253
7-78 Thermo Electron 8A Vehicle Test Accuracy Determination - Exhaust Gas 7-255
7-79 Thermo Electron 8A Diagnostic Test. 7-257
7-80 Thermo Electron 8A Durability Test Data 7-258

TABLES (CONT'D)

Number		Page
7-81	IBC N322 W/SC-400 Data Composite - Laboratory Test	7-266
7-82	IBC N322 W/SC-400 Data Composite - Repeatability Test	7-269
7-83	IBC N322 W/SC-400 Vehicle Test Accuracy Determination - Exhaust Gas	7-271
7-84	IBC N322 W/SC-400 Diagnostic Test	7-273
7-85	IBC N322 W/SC-400 Durability Test Data	7-274

Section 1

INTRODUCTION

This report documents the results of the Inspection of Vehicle Exhaust Emission Instruments Evaluation, EPA Contract 68-03-2353. This contract consisted of a survey of all available inspection/maintenance (I/M) type exhaust emission instruments and an assessment and selection for testing of approximately 20 instruments. Laboratory tests, vehicle exhaust gas response tests and instrument durability tests were conducted for each instrument. The final phase of the contract consisted of reports relating to work accomplished, comparative ratings of the instruments and recommendations/comments.

The purpose of this project was to assemble and collect information pertaining to availability, function, operation, performance, appearance, quality and relative test rating of I/M exhaust gas analyzers.

The scope of this project included a survey of all available I/M exhaust gas analyzers. The survey was used to develop a list of instruments to be procured for test evaluation. Following procurement of the instruments, a specified sequence of laboratory, vehicle and durability tests were conducted on each instrument. Relative performance ratings were determined based upon test results.

The survey that was conducted identified essentially all vehicle exhaust emission instruments from established instrument manufacturers that would be eligible for use in an I/M program. A table was constructed listing the instruments by application (HC, CO, NO_x), manufacturer, model, operating principle, range, specification (claimed or established, cost and availability. The final selection of instruments for procurement and testing was made in accordance with those instruments rated highest on the table and with additional requirements as delineated in the contract.

The final selection of instruments consisted of 17 units, three of which were NO_x analyzers.

Omissions of a specific instrument from this study does not, by itself, imply rejection of that instrument.

The scope of activities in this program is similar in some respects to ongoing or newly created I/M exhaust analyzer programs in various state and local government agencies. These programs range from simple review of manufacturing literature to complete operational checkout performed either by state government laboratories or by outside contractors. At present, California, New Jersey, Colorado, Arizona, and Nevada are active in I/M instrument review, with New York State and Rhode Island having programs in the planning stages. New York City also conducts an I/M instrument review.

Most state and local government instrument review programs require instrument manufacturer participation prior to sale for use in I/M programs in the respective state or locality.

All testing performed under this contract was carried out at the Anaheim, California facilities of Olson Laboratories, Inc., between June of 1976 and January of 1977, except for the high altitude test sequences. The high altitude test sequences were performed at Olson Laboratories' High Altitude Test Laboratory located in the City of Big Bear Lake, California, at an altitude of 6,750 feet.

1.1 MAJOR FINDINGS

The major findings of this program presented in generalized terms are as follows:

- A significant number of HC/CO I/M emission analyzers are presently available.
- Many different brands of instruments use common analytical benches with cosmetic changes for marketing purposes.
- Many HC/CO instruments include or are included in electronic engine diagnostic analyzers.
- The vast majority of HC/CO instruments are of an infrared absorption operating principle.
- General instrument designs have obviously been structured and influenced by state and local review agencies.
- Only two instruments with display/printout are available and both incorporate electronic diagnostic capability.
- Display and control design varies greatly and the ease of operation and use is different and correlates with design.
- There are very few NO_x instruments presently available for I/M use.
- Limited availability of NO_x instruments is probably due to very limited market demand.
- The majority of HC/CO instruments in this survey were adequate for I/M use.
- Most HC/CO instruments showed limited ability to handle the high volume of moisture, particulates, and heat encountered in loaded steady-state tests.
- In general, all I/M instruments tested met their respective advertised specifications.

- In general, all instruments were very insensitive to a ±10 percent change in input voltage. The maximum sensitivity observed on any instrument was 1 percent full scale.

- The hydrocarbon response characteristics of the HC/CO instruments generally showed greatest sensitivity to isobutylene followed by toluene, methane and ethylene. The units demonstrate essentially no sensitivity to acetylene and benzene.

- Instrument performance in actual vehicle testing showed that most instruments were capable of delivering acceptable exhaust concentration values in idle and loaded steady-state testing.

- Exhaust concentration variation during idle and loaded steady-state tests requires response time correlation when comparing the indications on two or more instruments. Instrument response time variation, noted in early response time tests, caused real-time sample correlation problems under dynamic vehicle exhaust conditions.

- Prolonged loaded steady-state testing caused early filter degradation on some instruments. Water accumulation in some lines occurred during these tests. The water accumulation indicated, in general, that if an instrument is to be used for a significant time in loaded steady-state or high rpm testing, an auxiliary sample conditioning or water removal system should be utilized to achieve maximum instrument performance.

- Instrument durability in sampling service, demonstrated in the durability tests, ranged from early failure to completion of approximately 1,000 hours of exposure to exhaust gases. Long-term use under exhaust conditions generally resulted in repetitive filter replacement, sample system degradation and blockage, water accumulation and analyzer degradation resulting in loss of response, increased response times, increasing drift and instability. Analyzer and sample system designs were most accurately characterized by performance observation during durability tests.

1.2 STATE OF THE ART

The instruments selected for this study represent the current state of the art in I/M emission analyzers. Typically, they provide adequate levels of repeatability in measuring exhaust gas emissions.

General analyzer cabinet design is sturdy and able to properly protect the analyzer package from typical environmental effects encountered in a garage environment. Ease of operation, calibration and mobility are directly related to cabinet design and control/meter layout. Several instruments exhibited design deficiencies that resulted in increased user effort and time-consuming delays in use and/or calibration.

Instrument mobility is greatly influenced by human factors engineering. The correct placement of handles and wheels with relation to human body size was apparent in many instruments but an apparent lack of regard to mobility was noted in some units. Wheel sizes ranged between 3 inches and 8 inches, arranged in two- or four-wheel combinations. During movement, the instrument/cart center of gravity (C.G.) plays an important role in the "feel of stability" or ease of mobility of each instrument.

Portable instruments were generally small and light enough to be used in a mobile mode of operation. HC/CO analyzer accuracy, using precision calibration gases and also when simultaneously sampling exhaust in parallel with an EPA-type analyzer bench is, in general, better than ±3 percent of full scale. This value is consistent with most state requirements for HC/CO analyzers. NO_x instruments tend to be more accurate than HC/CO instruments while analyzing precision gases. Their accuracy is on the order of ±1 percent of full scale. When sampling automotive exhaust, NO_x instruments tend to be much more sensitive to moisture contamination and this tends to degrade operational accuracy.

The operation of some HC/CO analyzers can be severely impaired by exposure to high temperature environments. In many cases, span and/or zero adjustment at high temperatures is insufficient for correct calibration. Typical failures appear to be a result of electronic malfunction due to overheating. Most instruments exhibiting malfunctions at high temperatures will recover to normal when operated again at room temperature. Low temperature operation tends to cause the same type of problem but the incidence is much lower.

Humidity variation affects the output of most HC/CO instruments. Variations of ±10 percent RH can cause a significant change in output level. Operation at high altitude cause malfunctions on some instruments resulting in symptoms similar to malfunctions at high temperatures. The principle detrimental operational effect of high altitude is insufficient zero/span adjustment to achieve correct calibration. Altitude compensation has apparently not been successfully implemented by all manufacturers.

The interference effects of various noninterest gases can be quite significant at specific temperatures, and carbon monoxide are the most dominant interference gases. Some analyzers exhibit cross-sensitivity between their HC and CO channels.

In general, most instruments showed response times of up to 30 seconds under extreme temperature and humidity conditions.

In some cases, the response time was a function of the specific design or sampling operation of the instrument. The general trend in response time indicated a range from slightly less than 10 seconds to approximately 30 seconds for 100 percent final reading.

Instrument zero drift at normal operating temperatures for a period of 4 hours, in many cases, can exceed ±3 percent of full scale. Temperature extremes generally serve further to degrade zero drift performance.

Instrument warm up times at normal room temperature were generally less than 30 minutes. Most state specifications require 30-minute warm up times for all temperature and humidity conditions. Both high and low temperature tests indicated longer warm up times than those at 70°F for most instruments. Temperature-related drift at the extremes may account for the apparent increased warm up times by masking the warm up performance with meter drift.

Section 2

INSTRUMENT SURVEY, SELECTION, AND PROCUREMENT

This program was initiated by conducting a general survey to identify all manufacturers, assemblers or distributors of vehicle exhaust emission instruments that would be eligible for use in an I/M vehicle test program. I/M vehicle test programs typically utilize "garage-type" HC/CO or NO_x instrumentation, or second generation instruments based upon "garage-type" units. "Garage-type" instruments have achieved their own identity in the marketplace and, because of expansion and refinement of this type of product, they can easily be distinguished from so called "laboratory-type" instruments.

"Laboratory-type" instruments are usually not well suited for usage in a harsh environment. External and/or additional sample handling and conditioning systems are usually required when using "laboratory-type" instruments. "Garage-type" instruments usually incorporate all necessary sample handling and conditioning equipment.

In general, "laboratory-type" instruments demonstrate accuracies in the range of ±1 percent full scale. The requirements of inspection and maintenance of automobiles do not necessitate such a high degree of accuracy. Typical "garage-type" instruments demonstrate accuracies in the range of ±3 percent full scale.

The survey concerned itself only with established instrument manufacturers. It specifically excluded those manufacturers who only had prototype equipment available at the time of the survey. A specific requirement of the instrument survey was that the instruments identified must be readily available to the general public at the time of the survey.

Out of the 113 manufacturers contacted, 21 were found to have instruments available and applicable to this program. Combined, these 21 manufacturers produced 129 distinct HC/CO or NO I/M instruments.

2.1 INFORMATION SOURCES

The survey was structured as a literature search, followed by a general mailing and telephone survey.

The literature search utilized all available periodicals, trade journals and professional papers. The most productive sources for instrument manufacturers names were:

Automotive Engineering Magazine, May 1974 Issue.
(Special Issue on Instrumentation)

Instrumentation for Environmental Monitoring, Environmental Instrumentation Group, Lawrence Berkeley Laboratory, University of California, Berkeley, California, Volume I

Pollution Equipment News, Rimbach Publishing Company, 8550 Babcock Boulevard, Pittsburgh, Pennsylvania 15237. Various Volumes

Instruments and Control Systems, Chilton Company, Chilton Way, Radnor, Pennsylvania 19089. Various Volumes

Industrial Research, Dun Donnelley, 666 Fifth Avenue, New York, New York 10019. Various Issues

Pollution Engineering, Technical Publishing Company, 35 Mason Street, Greenwich, Connecticut 06830 . Various Issues

Motor, The Hearst Corporation, 1790 Broadway, New York, New York 10019. Various Issues

International Automotive Industries, Chilton Company, Chilton Way, Radnor, Pennsylvania 19089. Various Issues

Mandatory Vehicles Emission Inspection and Maintenance, Volume III. Prepared under Contract ARB1522 with State of California Air Resources Board by Northrop Corporation in association with Olson Laboratories, Inc., May 31, 1971

Environmental Science and Technology, American Chemical Society, 20th and Northampton Streets, Easton, Pennsylvania 18042. Various Issues

Thomas Register, Thomas Publishing Company, 461 Eight Avenue, New York, New York 10001

Instrument Accreditation Data Files, Olson Laboratories, Inc.

To supplement the literature search, appropriate state and local government agencies were identified and included in a general mail survey requesting manufacturers names known to them. The sources for state and local government agencies were:

Where to Find State Plans to Clean the Air, U.S. Environmental Protection Agency, Washington, D.C. 20460

Governmental Air Pollution Agencies, 1973-1974 Directory, Published by the Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213

Table 2-1 lists all state and local government agencies on the mailing list.

Out of 58 letters sent to various agencies, ten replies were received.

The results of the literature search and the agency mailing was compiled to produce a list of prospective manufacturers (Table 2-2). A general mailing was initiated based upon the prospective manufacturer's list. After a

Table 2-1.
LIST OF STATE AND LOCAL GOVERNMENT AGENCIES

Alabama Department of Health

State of Alaska, Department of Environmental Conservation

Division of Air Pollution Control Arizona

Arkansas Department of Pollution Control and Ecology

Air Resources Board, California

Bay Area Air Pollution Control, District, San Francisco

Los Angeles County Air Pollution District

Riverside County Air Pollution Control District

San Bernardino County Air Pollution Control District

Air Pollution Control Division Colorado Department of Health

San Diego County Air Pollution Control District

Air Compliance Section Dept. of Environmental Protection, Connecticut

Delaware Department of Natural Resources & Environmental Control

District of Columbia Dept. of Environmental Services

Department of Pollution Control, Florida

Environmental Protection Div. Dept. of Natural Resources, Georgia

Air Sanitation Branch Division of Environmental Health, Hawaii

Department of Environmental & Community Services, Idaho

Environmental Protection Agency, Illinois

City of Chicago Dept. of Environmental Control

Indiana State Board of Health

Air Quality Management Div. Iowa Dept. of Environmental Quality

Kansas State Dept. of Health

Division of Air Pollution Kentucky Dept. for Natural Resources & Environmental Protection

Air Control Section, Bureau of Environmental Health Louisiana Health & Social Rehabilitation

Department of Environmental Protection, Bureau of Air Pollution Control, State House, Maine

Bureau of Air Quality Control Maryland State Department of Health & Mental Hygiene

Table 2-1. LIST OF STATE AND LOCAL GOVERNMENT AGENCIES (Cont'd)

Division of Air Pollution Control Michigan Department of Natural Resources

Division of Air Quality Minnesota Pollution Control Agency

Mississippi Air & Water Pollution Control Commission

Missouri Air Conservation Commission

Montana State Dept. of Health & Environmental Sciences

Division of Air Pollution Control Department of Environmental Control, Nebraska

Bureau of Environmental Health, Nevada

New Hampshire Air Pollution Control Agency

New Jersey Bureau of Air Pollution Control Division of Environmental Quality Dept. of Environmental Protection

Environmental Improvement Agency, New Mexico

New York State Dept, of Environmental Conservation

Dept. of Natural & Economic Resources, North Carolina

North Dakota State Dept. of Health State Capitol

Ohio Environmental Protection Agency

Air Pollution Control Div. Environmental Health Services Oklahoma State Department of Health

Department of Environmental Quality,Oregon

Bureau of Air Quality & Noise Control Dept of Environmental Resources Commonwelath of Pennsylvania

Rhode Island Division of Air Pollution Control

South Carolina Department of Health & Environmental Control

South Dakota Dept. of Environmental Protection

Division of Air Pollution Control Tennessee Dept. of Public Health

Texas Air Control

Utah State Division of Health

Agency of Environmental Conservation Air Pollution Control, Vermont

State Air Pollution Control Board, Virginia

Washington State Dept. of Ecology

West Virginia Air Pollution Control Commission

Wisconsin Dept. of Natural Resources Bureau of Air Pollution Control & Solid Waste Disposal

Table 2-1. LIST OF STATE AND LOCAL GOVERNMENT AGENCIES (Cont'd)

Air Quality Division Department of
Environmental Quality, Wyoming

Environmental Quality Board,
Puerto Rico

Table 2-2.
LIST OF PROSPECTIVE MANUFACTURERS, ASSEMBLERS OR DISTRIBUTORS

Allen Testproducts Div.

Autoscan

Barnes Engineering Co.

Beckman Instruments, Inc.

Chrysler Motors Corp.

Horiba Instruments Inc.

Kal Equipment

Applied Power, Inc.

Peerless Instrument Co.

Robert Bosch Corp.

Stewart-Warner Alemite Sales Co.

Sun Electric Corp.

Snap-On Western Division

Acurex Corp.

AEG-Telefunken Corp.

Anacon Inc.

Analabs, Inc.

Analog Devices, Inc.

Analytical Instrument
Development

Antex Instruments, Inc.

Austron, Inc.

Edmund Scientific Co.

Baganoff Associates, Inc.

Baird-Atomic, Inc.

Bendix Corp.

Canadian Research Institute
Div. of Criterion Instruments

Catalytic Products Int'l Inc.

CEA Instruments

Celesco Industries

Cenco Instrument Corp.

Clayton Manufacturing Co.

Cleveland Controls, Inc.

Comspace Corp.

Del Electronics, Corp.

Devco Engineering Inc.

Drew Chemical Corp.

Drexelbrook Engineering Co.

Dynasciences Corp.

E. I. Du Pont Co.

Ecologic Instrument Corp.

Edmac Associates, Inc.

Scientific Technology, Inc.

Table 2-2. LIST OF PROSPECTIVE MANUFACTURERS, ASSEMBLERS OR DISTRIBUTORS (Cont'd)

Scott Research Laboratories, Inc.

Siemens Corp.

Systron-Donner Corp.

Technicon Industrial Systems

Thermo Electron Corp.

Thermo-Lab Instruments, Inc.

Thermotron Corp.

Tracor, Inc.

United Electric Controls Co.

United Systems Corp.

Hamilton Standard

ADI Div. of Contamination Control Inc.

Andros Inc.

Automotive Environmental System, Inc.

Varian Associates

Weathermeasure Corp.

Wemco Instrumentation Co.

Wilks Scientific Corp.

Crystal-X Corp.

Environmental Data Corp.

National Environmental Instruments Inc.

Purad Inc.

World Marketing Corp.

Sylvania

Panametric Inc.

Lear Siegler Inc.

Teledyne Analytical Instruments

Sears, Roebuck & Co.

Bacharach Instrument Co.

Joy Manufacturing Co.

EMP Telemetry

Energetics Science Inc.

Environmetrics, Inc.

Fisher Scientific Co.

Fluidynamic Devices Ltd.

Forte Engineering Div.

Frankling Gno Corp.

Gam Rad, Inc.

GCA Precision Scientific

General Devices, Inc. Instrumentaion Div.

General Dynamics Electronics Div.

Gulton Measurement & Control Systems Div.

Table 2-2. LIST OF PROSPECTIVE MANUFACTURERS, ASSEMBLERS OR DISTRIBUTORS (Cont'd)

Heusser Instrument Co.

Infrared Industries, Inc.

International Light, Inc.

Intertech Corp.

ITT Barton

Kontes

Lab Glass, Inc.

Laboratory Data Control

McMillan Electronics Corp.

Meloy Laboratories, Inc.

Theta Sensors

Mettler Instrument Corp.

MG Scientific

Mine Safety Appliances Co.

Monitor Labs, Inc.

Perkin-Elmer Corp.

Philco Ford Corp.

Philips Electronic Instruments Inc.

Photobell Co. Inc.

Phys-Chemical Research Corp.

Process & Instruments, Inc.

Process Computer Systems, Inc.

Raeco, Inc.

REM Scientific Inc.

Research Appliance Co.

Royco Instruments, Inc.

Sara Scientific Co.

Scanivalve, Inc.

Science Spectrum, Inc.

reasonable time period had elapsed, a telephone follow-up survey was initiated to attempt to contact all manufacturers not responding to the mailing. In all, 113 manufacturers were contacted in the survey. Not all manufacturers contacted had instruments that would be applicable to the specific application in question.

All data collected during the survey was compiled and all products meeting the general requirements of an I/M instrument were identified and a preliminary instrument list was developed (Table 2-3).

2.2 SELECTION CRITERIA

The 129 distinct models represent, in reality, packing or optional feature variations of a much more limited number of basic instruments. The scope of this program only allowed the acquisition of a limited number of these instruments. With the intent of acquiring a representative cross section of all identified instruments, a selection criteria was established based upon the optical bench utilized by each unit. Using the optical bench as the basis of selection, Table 2-4 was generated.

Selection within optical bench subgroups was aimed at identifying the simplest and/or most economical instrument incorporating all available emission testing features. Table 2-4 then, includes a representative of each optical bench sytle or design identified from Table 2-3. Table 2-4 lists more than one model for a few manufacturers. In these cases, the differences between models are packaging- or accessory-oriented. More than one model was presented to allow flexibility in choice of packaging and to increase the chances of immediate availability.

Some instruments were excluded during the selection period due to unavailability of product. Specifically, Andros and Robert Bosch Corporation were unable to supply units due to discontinuance of production or lack of stock. Mine Safety Appliance was excluded due to lack of applicable product at time of selection. McMillan Electronics was excluded due to a prohibitive delivery schedule. World Marketing Corporation could not be located nor were they ever contacted by telephone. Their inclusion in the initial survey was based upon information gathered in the government agency general mailing.

Table 2-3 listed all instruments that were considered as candidates for testing. A subjective elimination of many instruments discovered in the survey was made based upon their complexity and unsuitability for use in the subject application. Although some instruments discovered in the survey could be utilized for the measurement of raw automotive emissions, their intended application was not consistent with the specific application as presented in the contract. Use of these instruments in the subject application would require extensive sample handling systems and higher operator skills not consistent with the intent of I/M level activity.

2.3 SURVEY RESULTS

The results of this survey indicate that with the exception of Horiba Instruments, Inc., no manufacturers are marketing NO instruments for the

Table 2-3.
PROSPECTIVE INSTRUMENTS
WITH MANUFACTURER CROSS INDEX

Manufacturer's Name		Instrument Model
Andros Instruments for Life		Model 218
Allen -	Allen	23-060-CA
	Allen	23-070-CA
	Allen	23-080-CA
	Allen	23-160-CA
	Allen	23-170-CA
	Allen	23-180-CA
	Allen	18-090-CA
	Allen	18-150-CA
	Allen	18-190-CA
	Allen	18-250-CA
	Amserv	23-067-CA
	Amserv	23-077-CA
	Amserv	23-087-CA
	Amserv	23-167-CA
	Amserv	23-177-CA
	Amserv	23-187-CA
	Amserv	18-097-CA
	Amserv	18-157-CA
	Amserv	18-197-CA
	Amserv	18-297-CA

Table 2-3. PROSPECTIVE INSTRUMENTS WITH MANUFACTURER CROSS INDEX (Cont'd)

Manufacturer's Name		Instrument Model
Allen -	MTSE	23-0660CA
	MTSE	23-076-CA
	MTSE	23-086-CA
	MTSE	23-166-CA
	MTSE	23-176-CA
	MTSE	23-186-CA
	MTSE	18-096-CA
	MTSE	18-156-CA
	MTSE	18-196-CA
	MTSE	18-296-CA
	Rotunda	23-065-CA
	Rotunda	23-075-CA
	Rotunda	23-085-CA
	Rotunda	23-165-CA
	Rotunda	23-175-CA
	Rotunda	18-095-CA
	Rotunda	18-155-CA
	Rotunda	18-195-CA
	Rotunda	18-255-CA
		Triple - A
		Commercial Electronics #715
Autoscan -	Autoscan	700 HC/CO
	Autoscan	705

Table 2-3. PROSPECTIVE INSTRUMENTS WITH MANUFACTURER CROSS INDEX (Cont'd)

Manufacturer's Name		Instrument Model
Autoscan -	Autoscan	705-C
	Autoscan	710
	Autoscan	710-C
	Series	4000 IR-C
	Rotunda	LLRE 705
	Rotunda	LLRE 710
	Rotunda	LLRE 4000 IR
Barnes -	Barnes	1836C
	Barnes	8335C
	Barnes	8335T
	Christie	EA-74C
	Christie	EA-74
	King	770C
	King	770
	Texaco	8335T
	Fox	1800
	Milex	1805
	Milex	1856
Beckman - Chrysler	Beckman	590
	Chrysler	IIIC
	Chrysler	23-066
	Chrysler	23-076

Table 2-3. PROSPECTIVE INSTRUMENTS WITH MANUFACTURER CROSS INDEX (Cont'd)

Manufacturer's Name		Instrument Model
Chrysler -	Chrysler	23-086
	Chrysler	18-096
	Chrysler	18-156
Chrysler Master Technician		HCE-211C
	Mopar	IIIC
	MTSE	IIIC
	Scott	IIIC
	Sun	1-300C
Emission Control Instruments	Sears	713.21022
IBC Celesco		N322W/SC-400 (NO)
Hamilton Test Systems	HTS	759464-2
	HT	200067
	Autosense	200
Horiba Instruments, Inc.	GSM	300
	GSM	300A
	GSM	300CA
	MEXA	300
	MEXA	300A
	MEXA	240 (NO)

Table 2-3. PROSPECTIVE INSTRUMENTS WITH MANUFACTURER CROSS INDEX (Cont'd)

Manufacturer's Name		Instrument Model
Kal Equip Company -	Kal Equip	4094C
	Kal Equip	4094D
	Bal Kamp	14-4787C
	Bal Kamp	14-4787D
	Poweready	370-400
	Poweready	370-400C
	Poweready	370-400D
	AC	ST-500
	AC	ST-500A
Marquette Manufacturing Company	Marquette	42-159
	Marquette	42-153
	Marquette	40-222
	Marquette	40-225
	Marquette	42-160
	Rotunda	BRE 42-732
	Rotunda	BRE 42-730
	Atlas	AET-345
	Atlas	AET-340
	Atlas	ADC-120 CMAE
	Atlas	ADC-120 CME
	Atlas	AET-330

Table 2-3. PROSPECTIVE INSTRUMENTS WITH MANUFACTURER CROSS INDEX (Cont'd)

Manufacturer's Name		Instrument Model
McMillan Electronics -	MEC	2300 (NO)
Mine Safety Appliance -		Model 303
Peerless Instrument Company -		Model 660
		Model 660C
	Pulsar	662
Robert Bosch	EFAW	289
Snap-On Tools Corp.		MT-495
(Marquette)		MT-496
		MT-496S
Stewart-Warner		3160-AC
		3160-ACI
		3161 Mfg. by Kal Equip
Sun Electric Corp.		EPA-75
		EET-910-1
		U-912-1
		EET-947
		EET-945
		2001
	Atlas	AET-330
Thermo Electron		Model 8-A (NO)
World Marketing Corp.		EIR-101 Marc 1

INSTRUMENT NAME	MANUFACTURER	OPERATING PRINCIPAL	STATUS P=PROD. PT=PROTO	SPECIFICITY	RANGE	ACCURACY LOW RANGE	SENSITIVITY	RESOLUTION LOWEST SCALE	LINEARITY	STABILITY	REPEATABILIT
MEXA 300A	HORIBA	DB NDIR	P	HC/CO	0-400/2000 PPM 0-2%/10%	<3% FS	NS	0.1% CO 10PPM HC	NON LINEAR	NS	±2% FS
MEXA 240	HORIBA	DB NDIR	P	NO	0-1000 PPM 0-4000 PPM	10 PPM 1% FS	NS	10 PPM	NON LINEAR	NS	±1% FS
BARNES 1836	BARNES ENG'G. CO.	NDIR DB	P	HC/CO	0-400/2000 PPM 0-2%/10%	±3% FS	NS	.05% CO 10PPM HC	NON LINEAR DISPLAY	NS	NS
BARNES 8335	BARNES ENG'G. CO.	NDIR DB	P	HC/CO	0-400/2000 PPM 0-2%/10%	±3% FS	NS	0.5% CO 10 PPM HC	LINEAR DISPLAY	NS	NS
MT 4965	SNAP-ON TOOL	NDIR DB	P	HC/CO	0-1000/2000 PPM 0-5%/10%	±3% FS	NS	0.1% CO 10 PPM HC	NON LINEAR	NS	NS
MODEL III C SCOTT	SCOTT E.T. (CHRYSLER)	SB NDIR	P	HC/CO	0-300/2000 PPM 0-.5%/10%	±2% FS	NS	0.01% CO 10 PPM HC	NON LINEAR	NS	NS
MARQUETTE 42-160	APPLIED POWER	DB NDIR	P	HC/CO ENGINE RPM	0-1000/2000 PPM 0-3000 RPM 0-5%/10%	±3% HC/CO ±2% RPM	NS	10 PPM 0.1% 100 RPM	NON LINEAR	±3% FS DRIFT/1 HR	±2% FS @5 SAMPLES
BECKMAN 590	BECKMAN	DB NDIR	P	HC/CO	0-400/2000 PPM 0-2%/10%	12 PPM HC 0.06% CO	NS	0.05% 10 PPM	NON LINEAR	NS	NS
3161	STEWART WARNER	SB NDIR ROT. FILTER	P	HC/CO	0-500/2000 PPM 0-2.5%/10%	±3% FS	NS	0.1% 10 PPM	NON LINEAR	±3% AFTER 10MIN. WARM UP	±2% FS
3160 AC1	STEWART WARNER	DB NDIR	P	HC/CO	0-400/2000 PPM 0-2%/10%	NS BUT HORIBA <3% FS	NS	0.1% 10 PPM	NON LINEAR	NS	±1% FS
218	ANDROS	DB NDIR	P	HC/CO	0-400/2000 PPM 0-1%/10%	NS	NS	0.02% 10PPM	NON LINEAR	<1% DRIFT IN 24 HR	NS
EET-910-I	SUN	NDIR RPM	P	HC/CO/RPM	0-500/2000 PPM 0-2.5%/10% 0-3000 RPM	±2.5% FS	ELEC. NOISE <±0.5% FS	NS	NON LINEAR	<1% FS/HR <5% FS/24HR	NS
EPA-75	SUN	NDIR	P	HC/CO	0-500/2000 PPM 0-2.5%/10%	±2.5% FS	ELEC. NOISE <±0.5% FS	0.1% 10 PPM	NON LINEAR	<±1% FS/HR <±5% FS/24HR	NS
MODEL 2001	SUN	NDIR	P	HC/CO MISC. COMP.	0-2000 PPM 0-10%	±3% FS	NS	0.01% CO 1 PPM	NA	<±3% FS/1HR	±2% FS
MODEL 111-C	CHRYSLER	NDIR SB	P	HC/CO	0-300/2000 PPM 0-0.5%/10%	±2% FS	NS	0.01% CO 10 PPM	NON LINEAR	NS	NS
SEARS 713.21022	ECI/SUN	SELECTIVE COMBUSTION	P	HC/CO	0-500/2000 PPM 0-2.5%/10%	NS	NS	0.1% CO 25 PPM HC	LINEAR	<3%	NS
MODEL 8-A	THERMO ELECTRON	CHEMIL	P	NO	0-500 PPM 0-1000 PPM 0-5000 PPM	NS	5 PPM	10 PPM	LINEAR ±2%	SPAN- ±2%/HR ZERO ±10 PPM/HR	±2%
MEC 2300	McMILLAN ELECTRONICS	CHEMIL	P	NO	0-100 0-200 0-500 0-1000 0-2000 PPM	±1%	10 PPB	4 PPM	LINEAR 1% FS	ZO <0.2 PPM/RANGE SO 1%/DAY	NS
MODEL 4094-D	KAL EQUIP	NDIR	P	CO/HC	0-500/2000 PPM 0-2.6%/10%	±3% FS	NS	0.1% CO 10 PPM HC	NON LINEAR	<1% FS/HR	NS
PULSAR 662	PEERLESS	NDIR THERMOPILE	P	HC/CO	0-400/2000 PPM 0-2%/10%	NS	NS	0.05% CO 10 PPM HC	NON LINEAR	NS	NS
MODEL 705C	AUTO SCAN	DB NDIR THERMOCOUPLE	P	HC/CO	0-500/2000 PPM 0-2%/10%	±2%	NS	0.01% CO 10 PPM	NON LINEAR	NS	NS
MODEL 710C	AUTO SCAN	DB NDIR THERMOCOUPLE	P	HC/CO	0-500/2000 PPM 0-2%/10%	±2%	NS	0.1% CO 10 PPM	NON LINEAR	NS	NS
MODEL D3-160CA	ALLEN	NDIR	P	HC/CO	0-500/2000 PPM 0-2.5%/10%	HI LOW CO% 0.3 .075 HC(PPM) 60 15	NS	0.1% 10 PPM	NON LINEAR	Z+S DRIFT 2% FS MAX	NS
MODEL 23170	ALLEN	NDIR	P	HC/CO	0-500/2000 PPM 0-2.5%/10%	HI LOW CO% 0.3 .075 HC(PPM) 60 15	NS	0.1% 10 PPM	NON LINEAR	Z+S DRIFT 2% FS MAX	NS
MODEL 200 AUTOSENSE	HAMILTON TEST SYSTEMS	NDIR	P	HC/CO MISC COMPUTER	0-2000 PPM 0-10%	2% FS ? ±3% ?	NS	NS	NON LINEAR BUT PRINT OUT FORMAT	NS	NS
N 322 W/SC-400	IBC CELESCO	ELECTRO CHEM	P	NO, NO$_2$, NOX	0-500 PPM 0-1000 0-5000	±2% FS	±1% FS	10 PPM	LINEAR	SPAN 2% FS/24 ZERO 2% FS/24	0.5% FS

Table 2-4. ADVERTISED PERFORMANCE SPECIFICATIONS

BILITY	REPEATABILITY	RESPONSE TIME	WARM UP TIME	INTERFERENCE	TEMPERATURE RANGE	HUMIDITY RANGE	ALTITUDE COMPENSATION	FLOW/LEAK DISPLAY	CALIBRATION GAS REQD. OR AVAILABLE	MECH/OPTI/ELEC CALIBRATION	DISPLAY TYPE	AUXILIARY SIGNAL OUTPUT
	±2% FS	90% READING IN<10 SEC	<5 MIN	NS	NS	NS	NONE	FLOW ALARM LIGHT	YES	ELEC/OPTI	8" ANALOG METERS	NO
	±1% FS	90% FS IN 0.5 SEC SAMPLE LINE 75M	10 MIN	<5PPM NO W/H_2O SAT H_2 @ 78°F <5PPM NO FROM 10% CO, 15% CO_2 & 2000 PPM PROPANE	NS	NS	NONE	FLOW INDICATION	YES (REQ)	NO	ANALOG METER	0-100 MV
	NS	90% FINAL VALUE IN 7 SEC.	<10 MIN	NS	30°F-120°F	NS	YES	YES	YES	ELECTRONIC	8" ANALOG LIGHTED	NO
	NS	90% FINAL VALUE IN 7 SEC	<10 MIN	NS	30°F-120°F	NS	YES	YES CO_2 INDICATION	YES	ELECTRONIC	8" ANALOG LIGHTED	YES
	NS	90% FS < 10 SEC	15 MIN	NS	NS	NS	YES (TABLE) CORRECTION FACTORS	FLOW RESTRICTION INDICATOR	YES	ELECTRONIC	6" ANALOG METERS	NO
	NS	90% FS @ 6 SEC	5 MIN	NS	35°F-115°F	NS	YES (TABLE)	FLOW INDICATOR (LOW)	YES	ELECTRONIC	ANALOG METERS	YES 0 → -2V
% FS T/1 HR	±2% FS @ 5 SAMPLES	90% READING IN 10 SEC	<30 MIN	±1% OF GASES, H_2O, PARTICULATES	35°F-110°F w/10MPH WIND 0°F-130°F NO WIND	0-85% RH	YES (TABLE)	FLOW RESTRICTION/ INDICATOR	YES	ELECTRONIC	8" ANALOG METERS	NO
	NS	90% READING IN 5 SEC	<15 MIN	NS	35°F-110°F	NS	YES	FLOW RESTRICTION INDICATOR	YES	ELECTRONIC	8" ANALOG METERS	YES
% R 10 MIN. M UP	±2% FS	90% READING IN 10 SEC	10 MIN	NS	35°F-110°F	0-95% RH	YES (TABLE)	FLOW RESTRICTION SIGN	YES	ELECTRONIC	ANALOG METERS	NO
	±1% FS	90% READING IN <10 SEC	10 MIN	NS	NS	NS	AUTOMATIC W/USE OF CALIBRATION GAS	FLOW MONITOR (LOW)	YES (INTEGRAL CAL GAS)	MECHANICAL (ELECTRONIC)	ANALOG METERS	NO
% DRIFT 24 HR	NS	HI SCALE 90% @ 8 SEC LOW SCALE 90% @ 10 SEC	10 MIN	NS	NS	NS	YES	NO	YES	ELECTRONIC	ANALOG METERS	NS
%FS/HR FS/24HR	NS	95% READING IN 7 SEC	15 MIN	<0.1% FS CO FOR 15% CO_2	32°F-120°F	NS	NS	FLOW LIGHT (LOW)	YES	ELECTRO/ MECHANICAL	8" BACK LIGHTED ANALOG	NS
%FS/HR %FS/24HR	NS	95% READING IN 7 SEC	15 MIN	<0.1% FS CO FOR 15% CO_2	32°F-120°F	NS	NS	FLOW LIGHT (LOW)	YES	ELECTRONIC	8" BACK LIGHTED ANALOG	NS
%FS/1HR	±2% FS	90% READING IN 10 SEC	30 MIN	NEGLIGABLE	NS	NS	NS	LOW FLOW INDICATOR	YES	ELECTRO/ MECHANICAL (AUTOMATIC)	DIGITAL 1/2" LETTERS	NS
	NS	90% FS IN 6 SEC	30 MIN	NS	30°F-115°F	NS	TABLE	LOW FLOW INDICATOR	YES	ELECTRONIC	ANALOG METERS	NS
%	NS	90% FS IN 10 SEC	20-30 MIN	0.05% CO → HC HC → CO	NS	NS	NS	NONE	NO	ZERO ONLY	6" ANALOG METERS	NS
N- %/HR PPM/HR	±2%	0-90% 15 SEC	NS	NEGLIGABLE	-5 → +35°C	NS	NS	FLOW METER PRESS. GAGE	YES/NO	YES	ANALOG METER	NO
PPM/RANGE /DAY	NS	100% IN 30 SEC	NS	NOISE ±0.5% FS	+10°C → +45°C	10%-95% RH	NS	AUTOMATIC FAULT DIAGNOSTIC SYSTEM	YES	NO	ANALOG METER	YES 0-1V 0-100 MV
%FS/HR	NS	90% IN 10 SEC	2 MIN	NS	35°F-110°F	0-95% RH	TABLE	LIGHT FOR RESTRICTION	YES	YES Z+S	ANALOG METER 2 NEEDLES	NS
	NS	90% IN 10 SEC	10 MIN	NS	35°F-110°F	10-85% RH	NS	FLOW LIGHT	YES	YES	ANALOG METERS	NS
	NS	90% IN 7 SEC	5 MIN	NS	NS	NS	INTERNAL JUMPER PRESET	FLOW RESTRICTION LIGHT	GAS CAL. AVAILABLE	YES (PRIMARY)	8" ANALOG	NO
	NS	90% IN 7 SEC	5 MIN	NS	NS	NS	INTERNAL JUMPER PRESET	FLOW RESTRICTION LIGHT	INTERNAL GAS CAL. SUPPLIED	YES (SECONDARY)	8" ANALOG	NO
S DRIFT FS MAX	NS	90% IN 10 SEC	5 MIN	NS	NS	NS	SPAN ADJUST ON METER FACE	FLOW INDICATOR	YES	YES	ANALOG METERS	NS
DRIFT FS MAX	NS	90% IN 10 SEC	5 MIN	NS	NS	NS	SPAN ADJUST ON METER FACE	FLOW INDICATOR	YES	YES	ANALOG METERS	NS
	NS	NS	NS	NS	35°F-110°F	10-90% RH	NS	SIGNAL ON HAND CONTAINER OF RESTRICTION	YES	AUTOMATIC ELECTRONIC Z+S ADJUST	DIGITAL PRINT OUT	NS
2%FS/24 2%FS/24	0.5% FS	95% IN 10-30 SEC	20-30 MIN	SO_2	10-115°F	10-90% RH	NS	SC-400 HAS FLOW METER	CAL. GAS	NO	ANALOG	YES 0-10 MV 0-100 MV 0-1 VOLT

OPTI/ELEC BRATION	DISPLAY TYPE	AUXILIARY SIGNAL OUTPUT	POWER REQUIREMENT	OVERLOAD PROTECTION (EXTERNAL)	FILTER SYSTEM	SAMPLE HANDLING	AUXILIARY SAMPLE CONDITIONER	RANGE IDENTIFICATION	INITIAL COST	DELIVERY	SKILL REQUIREMENT
C/OPTI	8" ANALOG METERS	NO	115 VAC 60 HZ 110 VA	2A FUSE	PARTICULATE FILTERS WATER SEPARATOR	SUPPLIED 20' HOSE PROBE	NS	RANGE LIGHTS	$1990.00 w/CART	4 WKS	LOW
	ANALOG METER	0-100 MV	115VAC 220VAC } ±10% 50/60 HZ 75W	NS	PARTICULATE FILTERS WATER TRAP	SUPPLIED 20' HOSE PROBE	OPTIONAL NO_2	RANGE SWITCH	$3591.00	4 WKS	LOW
CTRONIC	8" ANALOG LIGHTED	NO	115VAC/60HZ 300W 95V→130V	NS	PARTICULATE 0.6M	SUPPLIED 20' HOSE PROBE	NS	RANGE SWITCH	$1885.00	4 WKS	LOW
CTRONIC	8" ANALOG LIGHTED	YES	116VAC/60HZ 300W 95V→130V	NS	PARTICULATE 0.6M	SUPPLIED 20' HOSE PROBE	NS	RANGE SWITCH	$1995.00	4 WKS	LOW
CTRONIC	6" ANALOG METERS	NO	120VAC/60HZ 4 AMPS	FUSED	PARTICULATE + WATER TRAP	SUPPLIED 20' HOSE PROBE BALLAST	NS	LOW SCALE RANGE LIGHT	$2119.90	2 WKS	LOW
CTRONIC	ANALOG METERS	YES 0 → -2V	115VAC ±10% 60 HZ 100 WATTS	NS	WATER TRAP	SUPPLIED 20' HOSE	NS	RANGE SWITCH	$1730.00	3 WKS	LOW
CTRONIC	8" ANALOG METERS	NO	115VAC ±10% 60HZ 2.5 AMPS	FUSED	PARTICULATE FILTERS WATER TRAP	SUPPLIED 20' HOSE	REQUIRED FOR DYNO USE	RANGE SWITCH	$1431.50	4 WKS	LOW
CTRONIC	8" ANALOG METERS	YES	115VAC ±10% 50/60 HZ 275 W	FUSED	WATER TRAP PARTICULATE FILTER-SELF DRAINING	SUPPLIED 25' HOSE	NS	RANGE SWITCH	$1850.00	1-2 WKS	LOW
CTRONIC	ANALOG METERS	NO	11-15.7 VDC 8.5 AMPS	NS	PARTICULATE FILTER WATER TRAP	SUPPLIED 20' HOSE	NS	RANGE SWITCH AND LIGHT	$971.25	30 DAYS	LOW
CHANICAL CTRONIC)	ANALOG METERS	NO	115 VAC 50/60 HZ	1 A FUSE	PARTICULATE FILTER WATER TRAP	SUPPLIED 20' HOSE	NS	RANGE SWITCH	$1920.00	30 DAYS	LOW
CTRONIC	ANALOG METERS	NS	115VAC/60HZ 3.6 A 100-130 VAC	NS	PARTICULATE FILTER	NS	NS	RANGE SWITCHES	$1995.00	30 DAYS	LOW
CTRO/ ECHANICAL	8" BACK LIGHTED ANALOG	NS	120VAC/60HZ 95→125VAC	NS	DUAL PARTICULATE FILTER WATER TRAP	SUPPLIED 25' HOSE	NS	RANGE SWITCHES	$2875.00	30 DAYS	LOW
CTRONIC	8" BACK LIGHTED ANALOG	NS	120VAC/60HZ 5.0 AMPS	CIRCUIT BREAKER	DUAL PARTICULATE FILTER WATER TRAP	NS	NS	RANGE PUSH BUTTONS	$2140.00	30 DAYS	LOW
CTRO/ CHANICAL MATIC)	DIGITAL ½" LETTERS	NS	115VAC/60HZ 10 AMPS	FUSED	2 PARTICULATE FILTERS 2 WATER TRAPS	SUPPLIED	NO	NA	$13,950.00	30 DAYS	LOW
CTRONIC	ANALOG METERS	NS	105-130VAC 60 HZ 100 WATTS	NS	DILATED HOSE TO COLLECT H_2O NO PARTICULATE FILTER	SUPPLIED 22' HOSE	NO	SWITCHES	$1403.00	30 DAYS	LOW
O ONLY	6" ANALOG METERS	NS	12 VDC	DIODE FOR REVERSE POLARITY PROTECTION	GLASS WOOL FILTER	SUPPLIED 18' HOSE + PROBE	NO	SWITCHES	$299.99	1-2 WKS	LOW
S	ANALOG METER	NO	115VAC/60HZ 225 WATTS	NS	NS	NS	NO	SWITCH	≃$3350.00	30-45 DAYS	LOW
	ANALOG METER	YES 0-1V 0-100 MV	115VAC/60HZ	NS	INTERNAL	NS	NS	SWITCH	≃$2840.00	4-6 MONTHS	MEDIUM
S +S	ANALOG METER 2 NEEDLES	NS	12 VDC	NS	PRIMARY + SECONDARY PARTICULATE FILTER	20' HOSE	NO	LIGHTS	$945.00	4 WKS	LOW
S	ANALOG METERS	NS	12 VDC 4/9.5 A MAX	15 A FUSE	PARTICULATE FILTER	HOSE	NO	SWITCHES	$1470.00	30 DAYS	LOW
S RIMARY)	8" ANALOG	NO	115VAC	CIRCUIT BREAKER	PARTICULATE FILTER (REMOTE)	REMOTE CONDENSER UNIT	NO	PUSH BUTTON	$1994.00	4-6 WKS	LOW
S CONDARY)	8" ANALOG	NO	115VAC	CIRCUIT BREAKER	PARTICULATE FILTER (REMOTE)	REMOTE CONDENSER UNIT	NO	PUSH BUTTON PLUS INDICATOR LIGHTS	$2346.00	4-6 WKS	LOW
S	ANALOG METERS	NS	115VAC/60HZ	NS	DUAL PART. FILTERS WATER TRAP SELF DRAINING	30' HOSE	NO	SWITCH AND LIGHT	$1753.50	30 DAYS	LOW
S	ANALOG METERS	NS	115VAC/60HZ	NS	DUAL PART. FILTERS WATER TRAP SELF DRAINING	30' HOSE	NO	SWITCH AND LIGHT	$1897.00	30 DAYS	LOW
OMATIC CTRONIC ADJUST	DIGITAL PRINT OUT	NS	115VAC/60HZ 20 AMP	NS	DUAL PARTICULATE FILTER WATER TRAP	30' HOSE	NS	NS	$10,017.00	30 DAYS	LOW
NO	ANALOG	YES 0-10MV 0-100MV 0-1 VOLT	115VAC/60HZ	FUSED	PARTICULATE + H_2O DROP OUT (REMOTE)	20' HOSE	YES SC-400	SWITCH	$3750.00	4-6 WEEKS	MEDIUM

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specific application of I/M automotive emission testing. Because of this fact, present NO instruments are typically sold to be installed in consoles or rack-mounted and are plumbed into an analytical bench sample system. As a result, price quotations from the NO instrument manufacturers were developed based upon the requirement that their instrument must "stand alone;" i.e., must have their own sample delivery and sample conditioning system. The quoted prices reflect that requirement. All NO instruments recommended for acquisition were production units readily available to any customer. The sample systems supplied are based upon the recommendations of the manufacturer and also would be readily available to anyone with the specific application of I/M automotive emission testing.

All HC/CO instruments recommended for testing were priced with standard sample handling packages typically included with purchase.

With reference to Table 2-4, the letters "NC" are used to mean that the manufacturer makes no claim or that the information was not available.

The NO instruments recommended for purchase included instruments using NDIR, chemiluminescence and electro-mechanical detection techniques. The HC/CO instruments recommended for purchase and testing included both NDIR single-beam and dual-beam with gas charged detectors, thermocouple or thermopile detectors, and selective combustion detection techniques.

Only two units, the Sun Model 2001 and the Hamilton Test Systems Model 200 Autosense, incorporate direct computer interface with the exhaust emission analyzer. Because of the relative high cost of these two instruments and to maximize the total number of subject instruments, only one computer interface instrument was recommended for purchase. The Sun Model 2001 uses the same analytical bench as the Sun EPA 75 which was recommended for purchase. Therefore, the Hamilton Test Systems Model 200 Autosense was recommended for purchase. This instrument does not share the same analytical bench with any other instrument in Table 2-4. Purchase of the Model 200 Autosense would allow acquisition of data on the performance of a computer interface exhaust emission analyzer, in addition to another distinct analyzer bench.

2.4 SELECTED INSTRUMENTS

The final selection of instruments included the following:

- HC/CO
  Horiba Mexa 300A
  Barnes 8335C
  Scott 3C
  Marquette 42-160
  Beckman 590
  Stewart Warner 3161
  Sun EPA 75
  Mopar 3C
  Sears 713.21022
  Kal Equip 4094-D
  Pulsar 662
  Autoscan 710C

Allen 23-160CA
Autosense 200

- NO
  Horiba Mexa 240
  Thermo Electron 8A
  IBC N322 W/SC-400

The initial checkout of instruments for stable operation and hardware integrity was made at the time of instrument delivery. One instrument, Kal Equip, was returned upon this initial inspection due to shipping damage.

It was later replaced by the distributor. By late June of 1976, all the test instruments had been received and the laboratory test sequence was started.

Section 3

LABORATORY TESTS

Figure 3-1 depicts the sequential steps that were followed in the laboratory test program. The test sequence up to and including the response and recovery step was performed once daily for a period of 4 days. Upon completion of the response and recovery phase on the fourth day, all instruments were subjected to the voltage profile step prior to shut down.

Each test cycle was performed under carefully controlled temperature and humidity conditions. The first day the tests were conducted at ambient room temperature which was 21°C (70°F) at 50 percent relative humidity. The second day the tests were conducted at 43°C (110°F) at 70 percent relative humidity. The third-day tests were conducted at 2°C (35°F) at 85 percent relative humidity. The fourth-day tests were conducted at 21°C (70°F) at 85 percent relative humidity.

Following the voltage profile test, the instruments were subjected to a test to determine the effects of nonalkane hydrocarbons on their response. After the completion of the hydrocarbon response test, the barometric pressure test was performed.

The effects of barometric pressure were tested by relocating the test instruments to a high altitude test facility located approximately 6,750 feet above sea level. Olson Laboratories' emission lab in Analhim is approximately 300 feet above sea level.

The instruments were grouped in threes and fours for testing. Group determination was based upon the similarity between various instruments' scales and the ability to use the same calibration gases to set up a complete group of instruments.

Calibration gases used for this program were all purchased from the same gas supplier. The certified analytical accuracy of gas concentration was ±2 percent. The calibration gases were referenced by the supplier to either EPA-standard gases or National Bureau of Standards gases, depending upon their availability. Zero reference gas for all testing was dry nitrogen.

In addition to the analytical accuracy statement and naming of the specific gas blends by the gas supplier, Olson Laboratories used on-site equipment to specifically read each calibration gas and reference it to our in-house standard gases. Any gases that were found to be out of the ±2 percent analytical accuracy tolerence would be excluded from the program or carefully identified. (No gases were actually found to be out of this accuracy range.)

The specific description of each test in this program is presented below.

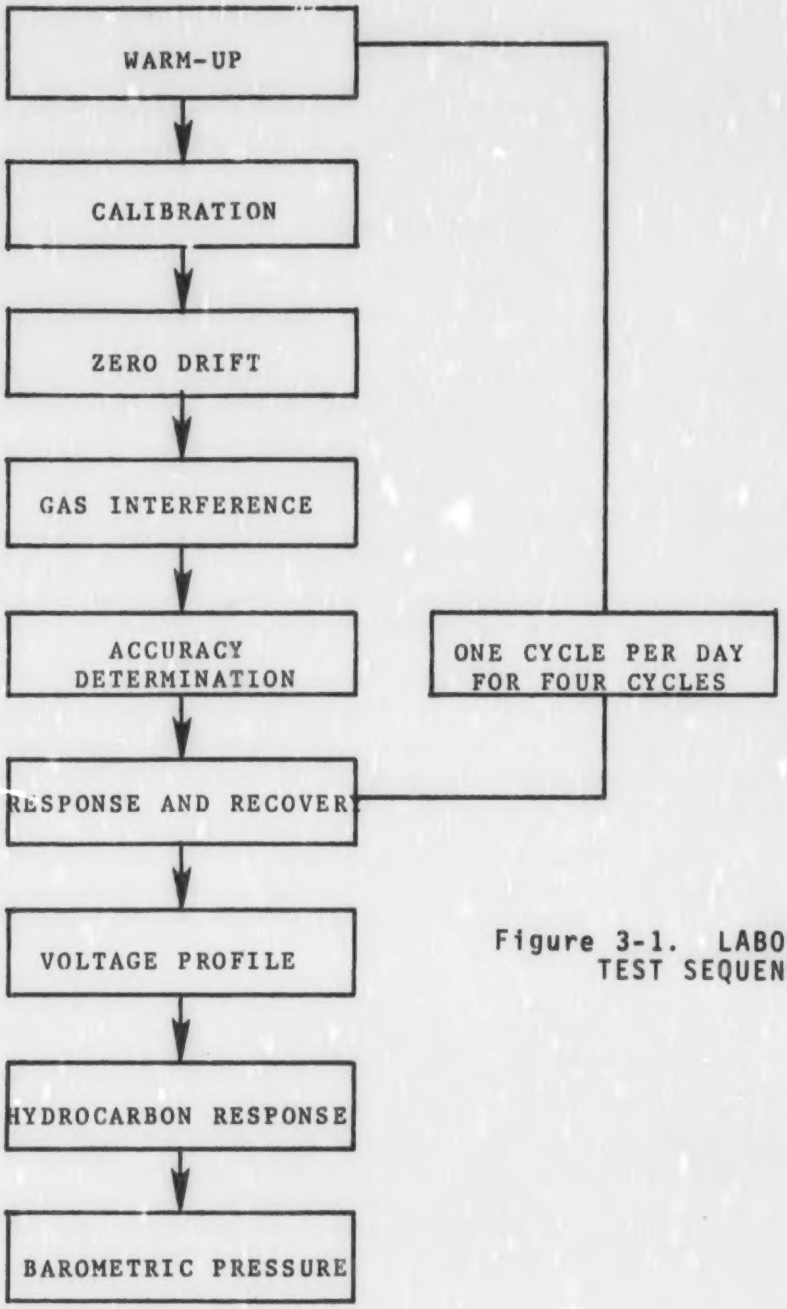
WARM-UP
CALIBRATION
ZERO DRIFT
GAS INTERFERENCE
ACCURACY DETERMINATION
ONE CYCLE PER DAY FOR FOUR CYCLES
RESPONSE AND RECOVERY
VOLTAGE PROFILE
HYDROCARBON RESPONSE
BAROMETRIC PRESSURE

Figure 3-1. LABORATORY TEST SEQUENCE

CYCLE	TEMPERATURE	RELATIVE HUMIDITY
1	70°F	50%
2	110°F	70%
3	35°F	85%
4	70°F	85%

3.1 INSTRUMENT WARM UP

The instrument warm up tests were performed based upon the instrument manufacturer's recommendations for warm up. Typically, power was applied to the instruments by front panel toggle switches or rotary switches. Input power for all instruments was controlled by front panel switches except for the Beckman 590.

The Beckman 590 has two front panel switch positions, "On" and "Standby." In the "Standby" position the instrument draws power but the operation's manual does not explain which devices in the analyzer are actually operating or are on a "Standby" mode. The Beckman 590 can only be turned off completely by unplugging the power cord. Warm up tests were performed on this instrument by switching the front panel toggle switch from the "Standby" to the "On" position. Prior to the start of the warm up test, all instruments, including the Beckman 590, were plugged into or connected to their appropriate power supply for a period in excess of 2 hours.

Warm up times were determined by taking successive meter readings at 30-second intervals after the instruments were turned on. When successive readings indicated stabilized operation, the data was backtracked to the beginning of the stabilized operation point. The time from initial power-on to the stabilized operating point was reported as the net warm up time. All instruments were set at mid-scale 1 minute after start. Meter deviation from the mid-scale set point was recorded as ppm for HC meter and percent for CO meter. Figure 3-2 shows a typical warm up time plot for an HC/CO instrument.

Determination of stabilized operation was hampered by the occurrence of zero drift. Some instruments exhibited significant zero drift in a stabilized condition (warmed up). It was observed that the occurrence of this significant zero drift tended to mask the initial point of stabilized operation for some instruments during the warm up test.

3.2 INSTRUMENT CALIBRATION

Following the warm up test, the instruments were calibrated in accordance with the manufacturer's instructions and rechecked with precision gases. Zero reference gas was dry nitrogen. The calibration points were recorded.

3.3 INSTRUMENT ZERO DRIFT

Instrument zero drift was noted every 30 minutes for a period of 4 hours during each test cycle. At the time of data collection, dry nitrogen was applied to the instrument. No adjustments were made on the instrument during the zero drift test. Data was reported as the maximum zero drift encountered during the 4-hour test, presented as percent of full scale. All zero drift tests were run on the lowest range available, since higher signal amplification is required for lower concentration measurements and any inherent drift will be more apparent.

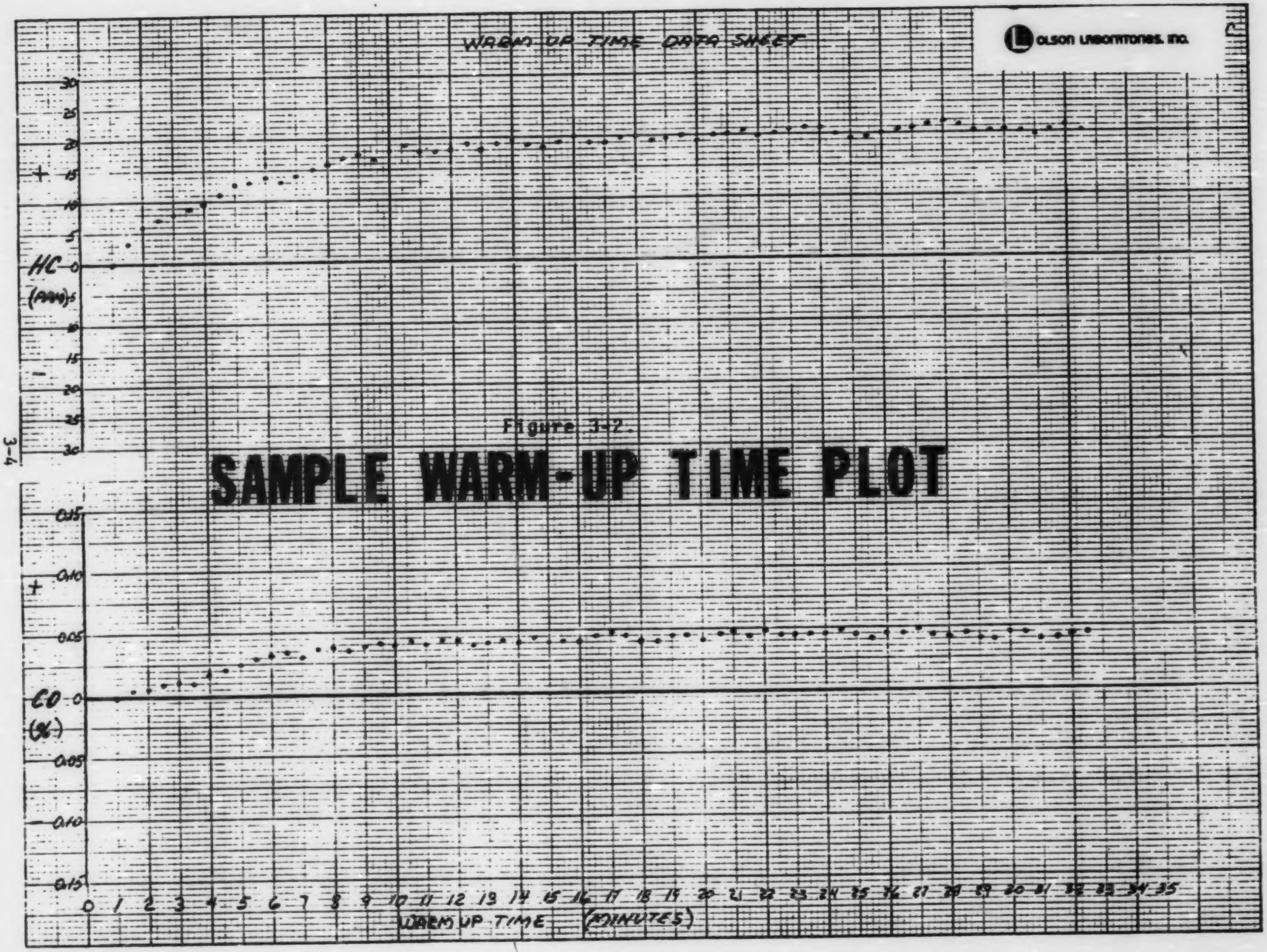

Figure 3-2.

SAMPLE WARM-UP TIME PLOT

3.4 INSTRUMENT GAS INTERFERENCE

The instruments were tested to determine their response to various gases and various moisture contents which they might encounter in normal service (in either an engine idle or loaded mode testing situation), but which they were not designed to analyze. By exposing the instruments to these various gases and moisture levels, the actual response of the instrument to these gases could be noted and recorded.

The following gases were used in the interference test: blend of 15 percent CO_2, background nitrogen; 1,600 ppm hydrocarbon (as hexane), background nitrogen; 10 percent CO, background nitrogen; 3 percent H_2O vapor in air (saturated), 2,000 ppm NO, background nitrogen; and 10 percent O_2, background nitrogen. Gas interference tests were run on all instruments in their lowest range. The 1,600 ppm hydrocarbon in N_2 sample used for gas interference testing was blended as 3,344 ppm propane. (With a propane equivalency factor of 0.52, the hexane equivalent would be 1,739 ppm.) Water vapor (H_2O) in air was generated with a bubbler under controlled temperature conditions. The data was reported as response (percent of full scale deflection) to each gas constituent.

3.5 INSTRUMENT ACCURACY DETERMINATION

A series of known, blended precision gases containing only analyzed amounts of HC, CO and NO with background nitrogen, were applied to each instrument. The instrument's response and measurement of the constituent for which it was designed was observed and used as a basis for its accuracy determination.

Accuracy determinations were made on all available ranges for all instruments. The data is presented as percent absolute error, calculated by comparing the instrument's reading to the known sample gas value. Percent full scale error was calculated by computing the variation of the instrument's reading from the sample gas value, then comparing with the full scale value of the instrument range in question.

All accuracy data was presented for three conditions on each range (35 percent, 70 percent and 100 percent of full scale). The fourth point in the accuracy determination, zero, is not reported since rezeroing was always accomplished prior to accuracy determination.

Accuracy determination was made for all four temperatures and relative humidity test cycles, plus the barometric pressure test.

3.6 RESPONSE AND RECOVERY

This test was run to determine the response time of each instrument. Using a switching valve, alternate applications of a span gas of known concentration followed by a zero gas was made. The sample gas was introduced into the instrument's exhaust sampling probe (tail pipe probe). Observed instrument response time represented the total analyzer and sample system response time for each instrument.

The data was reported as the average of two runs for each component of interest. High range was used on all instruments during all response tests. The corrected concentration of HC represents the hexane equivalent of 3,300 ppm propane in nitrogen gas sample. The instrument's propane equivalency factor was used to calculate the corrected concentration.

The time span was measured on each instrument from the time the switching valve was turned to the sample gas to the time when the instrument response leveled off. The data was reported as response time in seconds and was the average of two runs. This response time represents time required for full scale readings and is not consistent with various advertised ratings that call out response time to 90 percent full scale reading.

3.7 VOLTAGE VARIATION

This test demonstrates the effects of line voltage fluctuation. It was executed by applying calibration gases of known concentration to the instrument while varying its input voltage plus and minus 10 percent from nominal. Voltage profile tests were run with the instruments in the highest available range. Supply voltages of 115 VAC and 13.6 VDC were varied plus 10 percent and minus 10 percent using variable power supplies.

The HC and CO analyzers were supplied 3,300 ppm propane and 8.1 percent CO sample gas. The NO analyzers were supplied 3,400 ppm NO sample gas. The data was presented as reading variation in percent of full scale.

3.8 HYDROCARBON RESPONSE

Most hydrocarbon instruments specifically designed for automotive inspection or maintenance testing are designed and sensitized to read total hydrocarbons. Thus, the response of instruments to specific hydrocarbon groups was tested.

Various other gases found in automotive exhaust emissions, including both aliphatic and aeromatic hydrocarbons, were introduced into the instrument. The specific gases used were acetylene, benzene, ethylene, isobutylene, methane and toluene, (all approximately 300 ppm in nitrogen).

Hydrocarbon response tests were run on each HC/CO instrument at altitudes of 300 feet and also at the high altitude laboratory located at 2,057.4 meters (6,750 feet).

All instruments except the Sears were run on low range. Because of the Sears higher response to various hydrocarbons, it was necessary to run the Sears unit on high range.

The data for hydrocarbon response was presented as hydrocarbons in ppm.

3.9 REPEATABILITY TESTS

Following the Laboratory Barometric Pressure Tests, the instruments were subjected to a series of repeatability tests. These tests consisted of the following laboratory test sequence steps: warm up, calibration, zero drift, gas interference, accuracy determination, and response and recovery. The instruments were cycled through these sequence steps four times. All testing was accomplished at laboratory ambient temperature and humidity. The data generated indicates the instrument's level of repeatability (see Figure 3-3).

3.10 FACILITIES

The laboratory test sequence of warm up through response and recovery was carried out utilizing the environmental chamber in Olson Laboratories' emissions lab. This environmental chamber allows close control of temperature and humidity. The temperature range capability of this environmental chamber is approximately $0^{\circ}C$ to $54.4^{\circ}C$ ($32^{\circ}F$ to $130^{\circ}F$). The humidity control range is approximately 5 percent RH to 95 percent RH. Control capability is in the order of ±1.1°C (±2°F) and ±5 percent RH. Figures 3-4, 3-5, 3-6, and 3-7 show various views of the environmental chamber.

The double-pane sliding glass doors allow complete visual observation of the instrument operation during the test sequence. All calibrations, adjustments and data acquisition were accomplished with the instrument technician inside the environmental chamber. Calibration gas control was achieved by utilizing a push button panel mounted inside the chamber, controlling gas solenoids mounted on the outer wall. These, in turn, were connected to the sample gas tanks.

All laboratory test sequences, except hydrocarbon response and barometric pressure tests, were accomplished inside the environmental chamber. The barometric pressure test was conducted at Olson Laboratories' high altitude facility located at an elevation of 2,057.4 meters (6,750 feet) in the City of Big Bear Lake, California. These tests took place in a controlled ambient temperature of approximately $21^{\circ}C$ ($70^{\circ}F$). Prior to testing at high elevation and also at the high altitude test site, the instruments were calibrated with the same precision gases used at Olson Laboratories' Anaheim facility (approximately at sea level). Figure 3-8 shows a plot plan of the high altitude test facility.

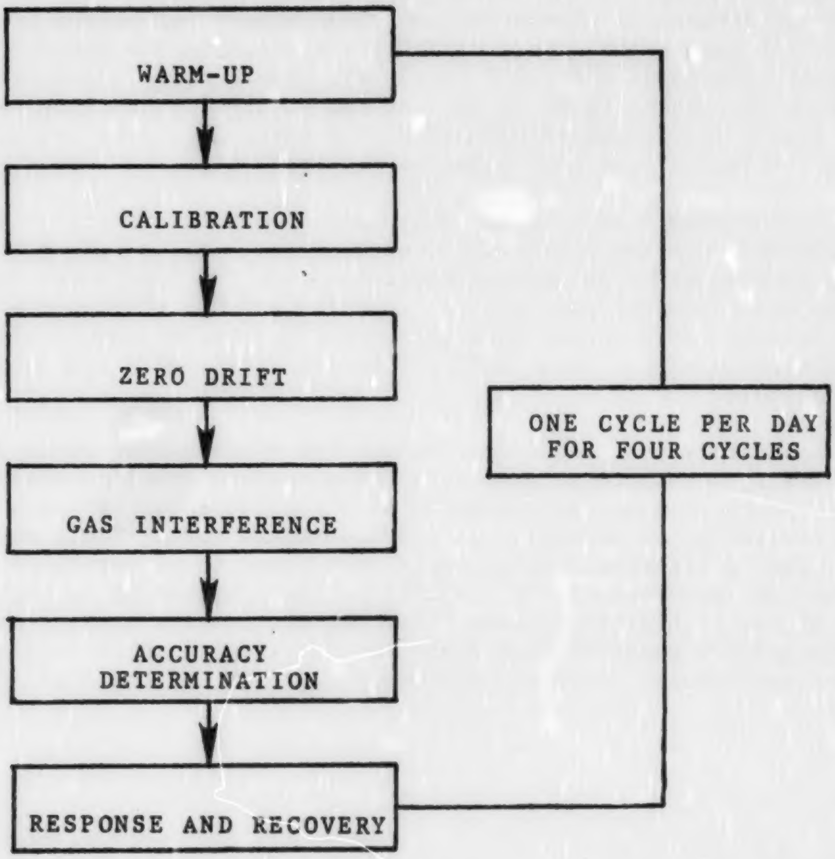
WARM-UP
CALIBRATION
ZERO DRIFT
GAS INTERFERENCE
ACCURACY DETERMINATION
RESPONSE AND RECOVERY
ONE CYCLE PER DAY FOR FOUR CYCLES

Figure 3-3. REPEATABILITY TEST
(All cycles conducted at laboratory ambient temperature and humidity)

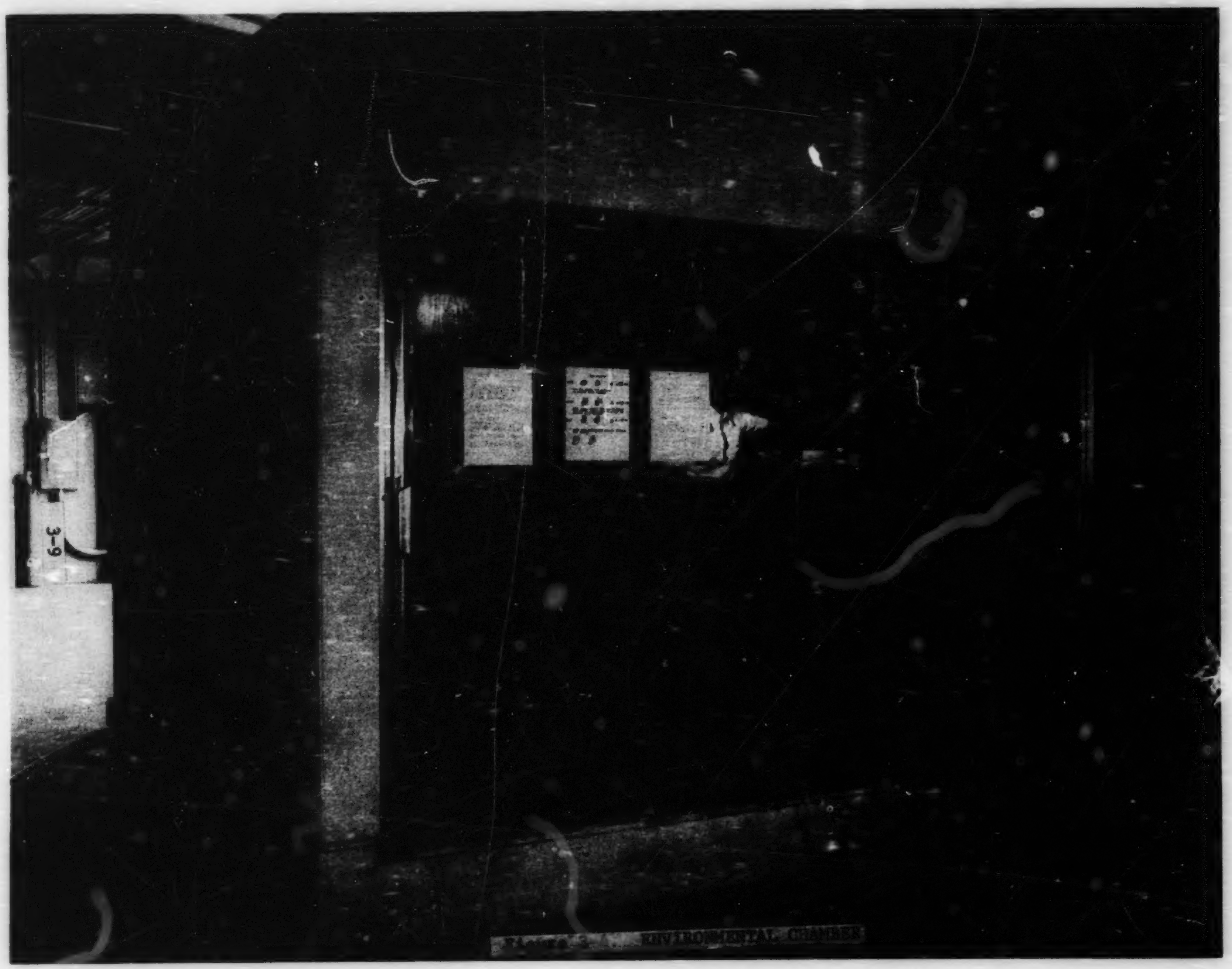

Figure 3-[illegible]. ENVIRONMENTAL CHAMBER

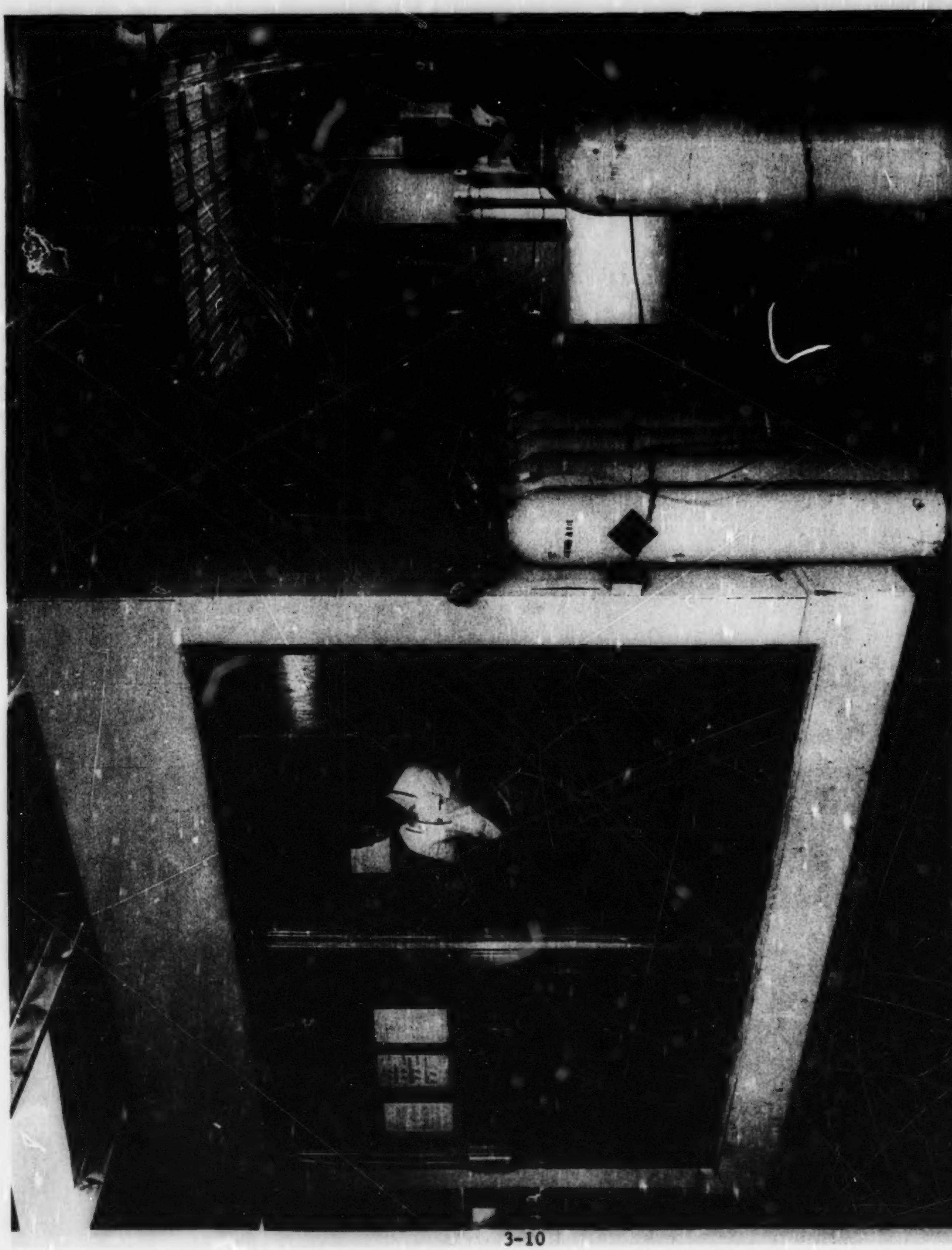

Figure 3-5. ENVIRONMENTAL CHAMBER WITH CALIBRATION GASES

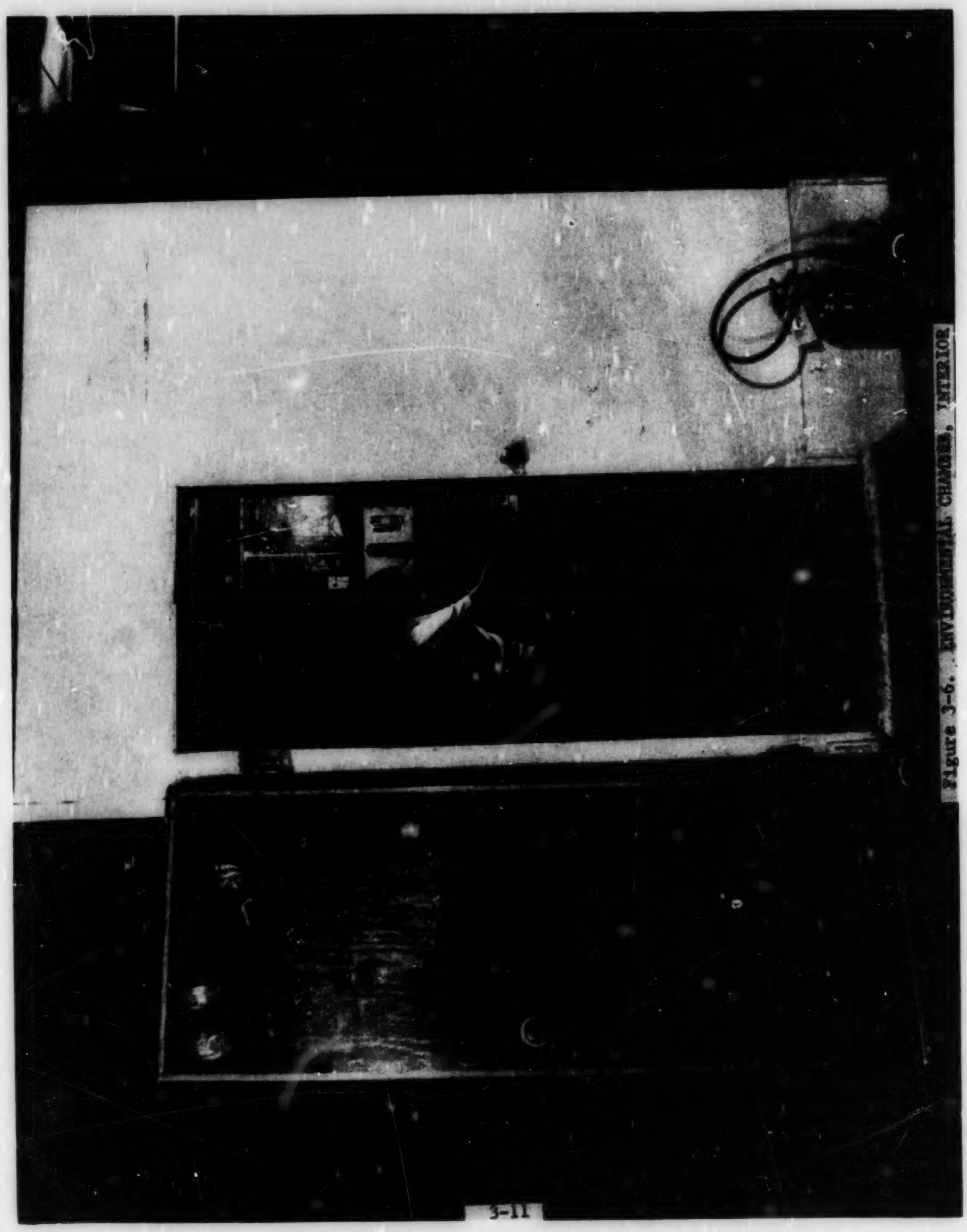

Figure 3-6. ENVIRONMENTAL CHAMBER, INTERIOR

Sun Exhaust Performance Analyzer
HYDROCARBON
CARBON MONOXIDE
HC
CO
SUN
SERVICE EQUIPMENT

Figure 3-7. INSTRUMENTS INSIDE ENVIRONMENTAL CHAMBER

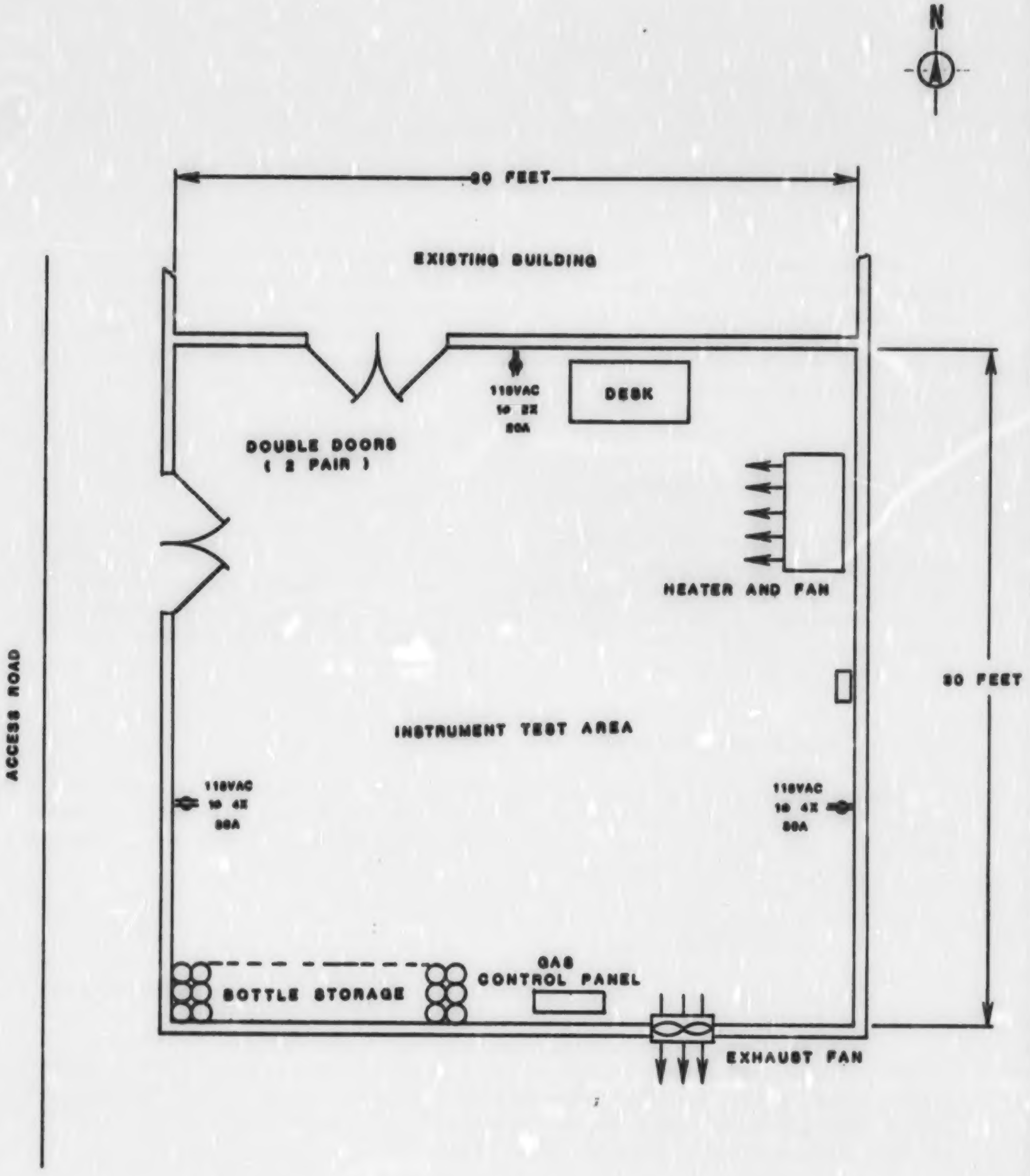
N
30 FEET
EXISTING BUILDING
115VAC
1Φ 2X
20A
DESK
DOUBLE DOORS
(2 PAIR)
HEATER AND FAN
30 FEET
ACCESS ROAD
INSTRUMENT TEST AREA
115VAC
1Φ 4X
20A
115VAC
1Φ 4X
20A
GAS
CONTROL PANEL
BOTTLE STORAGE
EXHAUST FAN

Figure 3-8
OLSON LABORATORIES INC. HIGH ALTITUDE TEST FACILITY
BIG BEAR LAKE CALIFORNIA
ELEVATION 6750 FEET

Section 4

VEHICLE TESTS

After completion of the laboratory test phase, the instruments were tested on a vehicle dynamometer to simulate typical operating conditions. In these tests an EPA-type analytical bench was used as the standard to determine instrument performance. Automotive exhaust gases were analyzed simultaneously by the EPA bench and test instruments, and these readings were compared. The vehicle test sequence is shown in Figure 4-1. A description of each test step follows.

4.1 INSTRUMENT WARM UP

The instruments were warmed up in accordance with the manufacturer's instructions. Typical warm up times were on the order of 1 hour to assure that all instruments were completely stable. The test vehicle was warmed up on the dynamometer and was run at 48.28 kph (30 mph) at a pre-set loaded steady-state road load for 15 minutes (Table 4-1). The EPA analytical bench was warmed up for approximately 2 hours.

4.2 INSTRUMENT CALIBRATION

The instruments were calibrated using zero and laboratory span gases as specified by the instrument manufacturer. The span gases were ±2 percent analysis. The zero gas was dry nitrogen. The zero and span gas values and the calibration points for each instrument were recorded.

4.3 LOADED STEADY-STATE

The test vehicle was run on the dynamometer under loaded conditions at 72.42 kph (45 mph), 48.28 kph (30 mph) and idle (Table 4-1).

The loaded steady-state test was run with the vehicle engine in its normal, properly adjusted condition. No modifications were made at this point. Tail pipe emissions were sampled simultaneously using the EPA analytical system and the test instruments. The test instrument reading was then compared to the reading of the EPA analytical system.

4.4 LEAN LOADED STEADY-STATE

Prior to running the lead loaded steady-state test, the test vehicle carburetor was adjusted for a lean air/fuel mixture at idle. The EPA analytical system was used to monitor CO. A reading of 0.5 to 1.5 percent CO was the adjustment target. After adjustment, the vehicle was tested under loaded conditions at 72.42 kph (45 mph), 48.28 kph (30 mph), and idle (Table 4-1).

VEHICLE TEST SEQUENCE

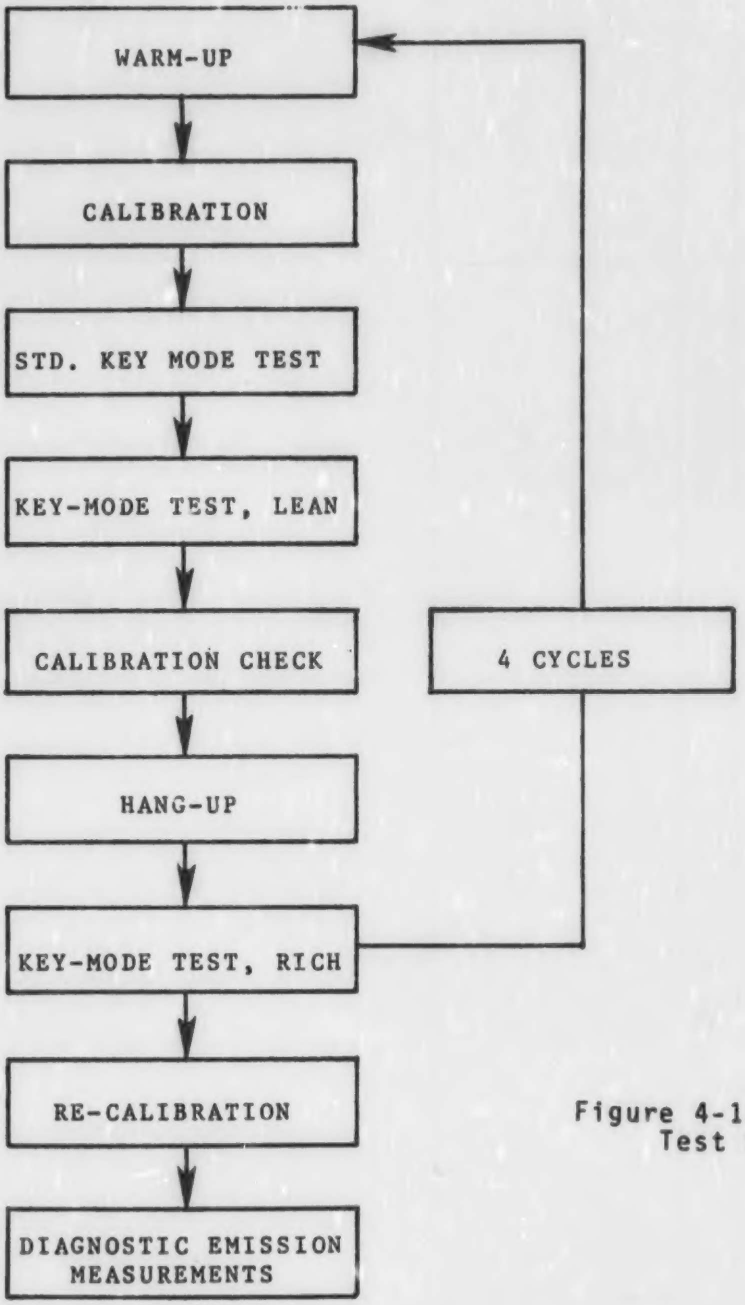
WARM-UP
CALIBRATION
STD. KEY MODE TEST
KEY-MODE TEST, LEAN
CALIBRATION CHECK
HANG-UP
KEY-MODE TEST, RICH
RE-CALIBRATION
DIAGNOSTIC EMISSION MEASUREMENTS
4 CYCLES

Figure 4-1. Vehicle Test Sequence

CYCLE	TEMPERATURE	RELATIVE HUMIDITY
1-4	70°F ± 5°F	50% ± 10%

Table 4-1.

LOADED STEADY STATE HORSEPOWER VALUES FOR LOADED VEHICLE TEST

VEHICLE WEIGHT	LOW CRUISE		HIGH CRUISE	
	SPEED (KPH/MPH)	LOAD (WATTS/HP)	SPEED (KPH/MPH)	LOAD (WATTS/HP)
2800-3800	48.28/30	6711/9	72.42/45	17,151/23

Emissions were tested simultaneously at the tail pipe with the EPA system and the test instrument. The readings were then compared.

4.5 CALIBRATION CHECK

Immediately following the lean loaded steady-state test, the test instrument probe was removed from the vehicle exhaust pipe.

Zero calibration and span calibration was checked and the results recorded. The zero gas used for this check was dry nitrogen. The span gas used was ±2 percent analysis and was based upon the manufacturer's recommendations for concentration.

4.6 INSTRUMENT HANG-UP

Following the calibration check, the instrument hang-up time was determined. To perform the hang-up response a sparkplug wire was removed from the test vehicle. This immediately caused the HC emissions to increase significantly.

The instrument sample probe was inserted in the exhaust stream of test vehicle. After a reading was generated, the probe was quickly removed. The time required for the instrument meter to return to zero was recorded as hang-up time. The data is reported as the average of two tests.

4.7 RICH LOADED STEADY-STATE

After the hang-up test, the test vehicle carburetor was adjusted to achieve a rich air/fuel mixture at idle. The EPA analytical system was used to set the air/fuel mixture. Exhaust emissions were sampled simultaneously with the test instrument and the EPA system with the vehicle running at 72.42 kph (45 mph), 48.28 kph (30 mph), and idle (Table 4-1). The readings of both systems were then compared.

The entire sequence from Instrument Calibration, (4.2) through Rich Loaded Steady-State (4.7) was repeated three times without turning off the instrument's vehicle or dynamometer and was reported as cycles one, two, three and four.

4.8 INSTRUMENT RECALIBRATION

Following the final fourth cycle of rhe Rich loaded steady-state test, each instrument was recalibrated as in Section 4.2.

4.9 DIAGNOSTIC EMISSION MEASUREMENTS

The distributor timing in the test vehicle was retarded by disconnecting the line to the vacuum advance mechanism. This altered the vehicle exhaust emission composition. The test instrument probe was inserted in the exhaust manifold connected to the test vehicle. While the test vehicle engine was idling, the exhuast emissions were measured and recorded simultaneously with the EPA system.

The vacuum line to the distributor vacuum advance was then reconnected and the vehicle exhaust emissions remeasured. Following this, a sparkplug wire was disconnected and idle emissions again recorded. A large increase in HC concentration was observed. Following this, the engine was put back into normal operating condition and the idle emissions again were measured and recorded. This diagnostic emission measurement sequence was performed only once, immediately following the fourth and final cycle of the vehicle test sequence.

4.10 EPA ANALYSIS BENCH AND CALIBRATION GASES

The EPA-Approved Analysis System for HC/CO and NO was constructed and assembled per 85.774-13 of the Federal Register, Volume 37, No. 221, November 15, 1972. The analytical bench assembled for use in this program consisted of two Beckman 315 NDIR analyzers for measuring HC and CO and a Horiba AIA-2 analyzer for measuring NO_x. The outputs for these analyzers were recorded on a Horiba Labocorder R-4T four-pen recorder. The analysis and sample handling system was modeled after the general flow schematic contained in the Federal Register.

Figure 4-2 shows the front view of the EPA analytical system with the four-pen recorder at the upper left. Figure 4-3 and 4-4 show the special exhaust manifold used for both the vehicle tests, and later for the diagnostic and durability tests. Both the probe for the EPA analytical system and the probe for the test instrument were inserted into the special exhaust manifold during testing.

4.11 EPA INSTRUMENT CALIBRATION

Calibrations were performed on the three analyzers using calibration gases with an analysis of ±2 percent as specified in the Federal Register. Propane was used for the HC analyzer, and the hexane equivalent was determined by using 0.52 as the propane equivalency factor. The 0.52 value was extracted from the calibration procedures included in the Federal Register under the applicable section.

The EPA instrument assembly was subjected to full calibration after each 30-day use. The same flow rate was used for calibration that was used for sampling exhaust gases. The 30-day calibrations were accomplished by shooting ten calibration gases plus a zero gas (10 points plus zero). A polynomial regression was used for the curve fit.

Daily calibrations utilized one up-scale gas per range plus zero. Before and after each cynamic test sequence, an up-scale gas plus zero was shot on each analyzer.

Dryer changes in the NO sample line were accomplished prior to each test sequence. The common sample manifold as shown in Figures 4-2 and 4-3 was constructed to supply exhaust sample to all the instruments simultaneously during the vehicle tests and the durability tests. Multiple sample ports were

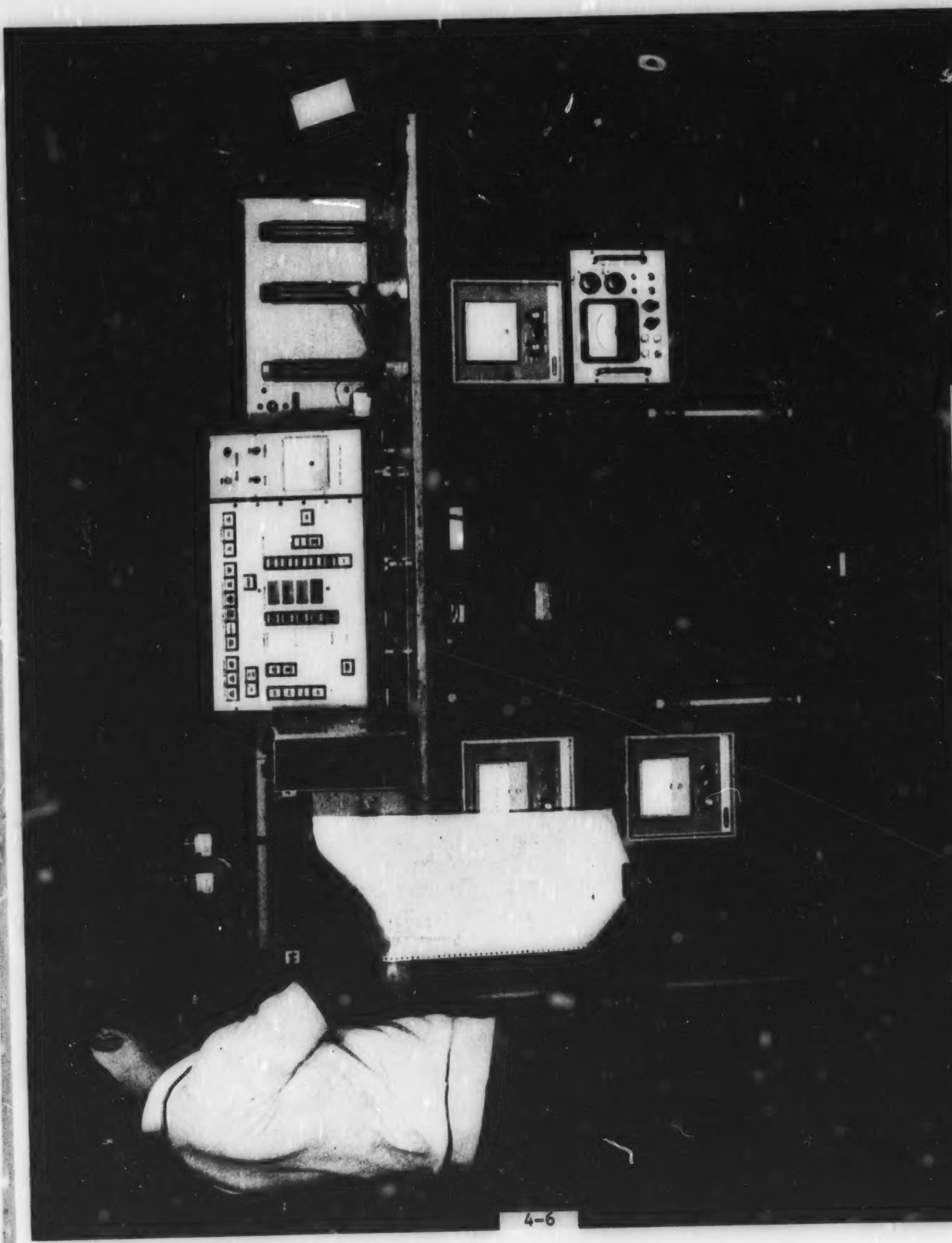

Figure 4-2. EPA ANALYTICAL SYSTEM

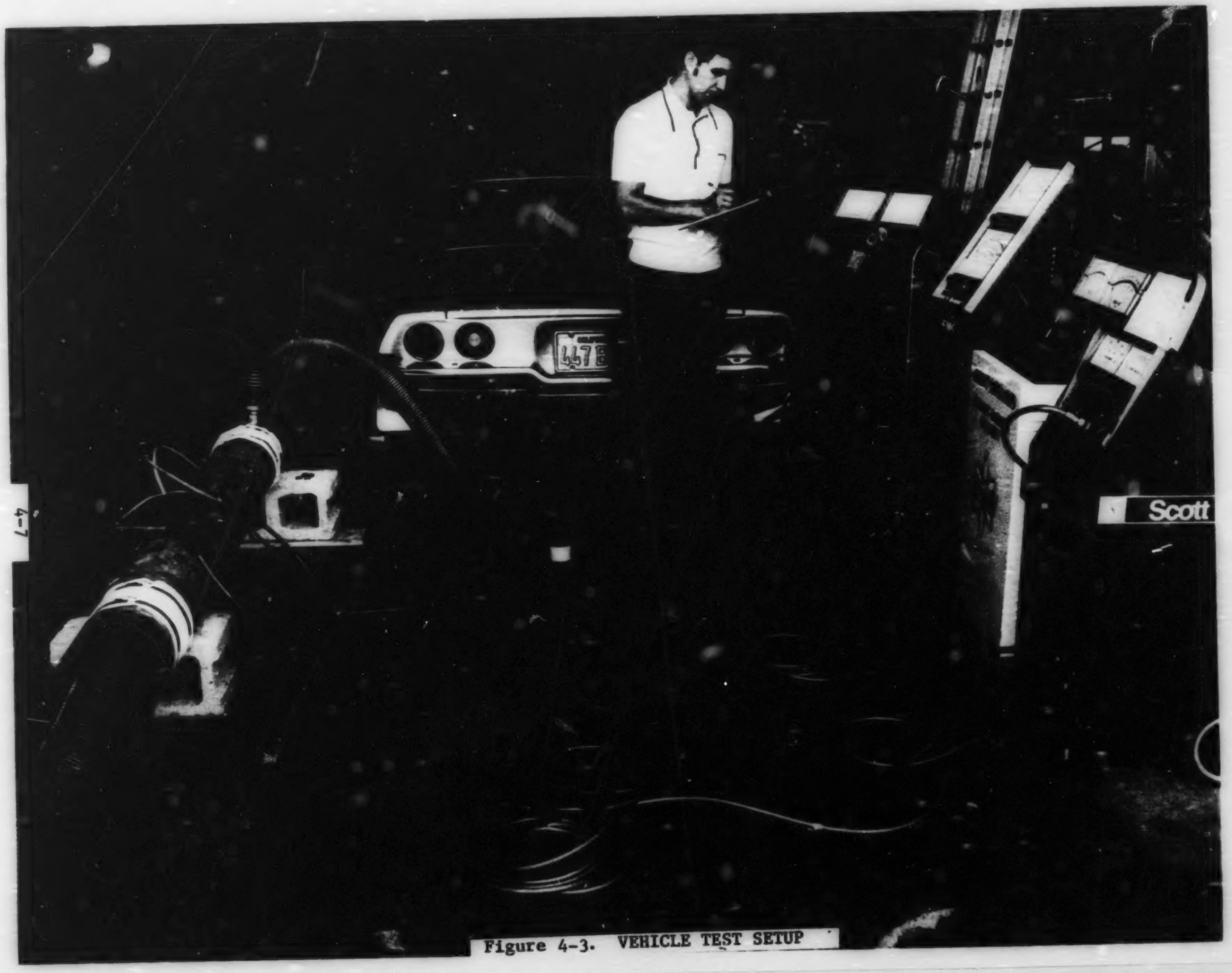

Figure 4-3. VEHICLE TEST SETUP

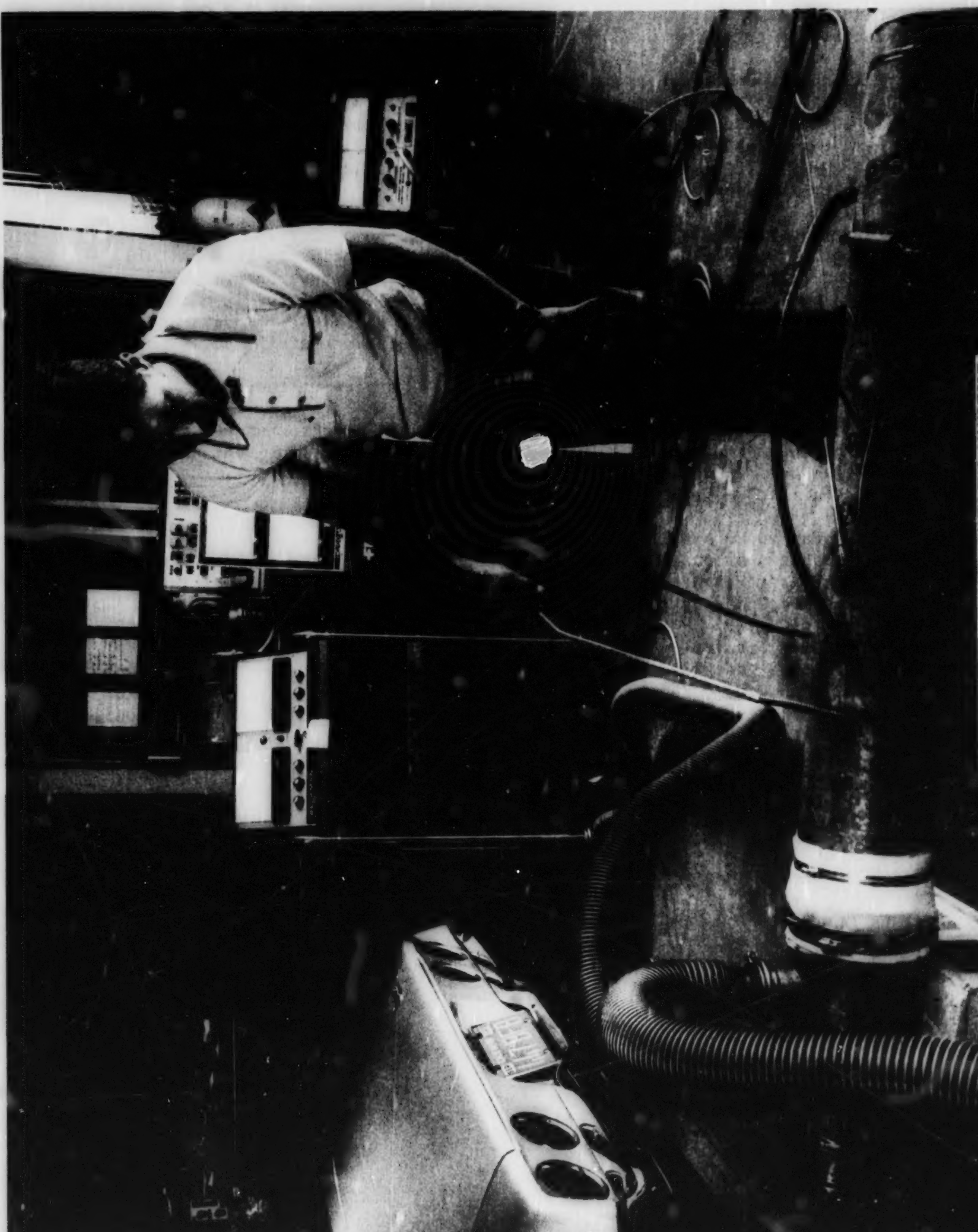

Figure 4-4. COMMON SAMPLING MANIFOLD

built into this sample manifold to allow the instrument probe's access to the exhaust stream.

All instrument probe positions were varied within the sample manifold ports on a daily basis during the durability tests. The size and shape of the sample manifold tended to allow significant exhaust mixing in the manifold. This, in turn, tended to reduce the concentration variations and spikes in the exhaust gases. The constituent make-up of the exhaust gases was not adversely affected by the sample manifold.

However, since the sample manifold tended to be cooler than the exhaust system on the vehicle, significant water fallout did occur in the manifold. This water fall-out indicated that the instruments may have been exposed to a slightly lower moisture level than they would have encountered in actual use when their probes were placed in the tail pipe of a vehicle. Modifications or special conditioning of the sample must be approached carefully so as not to alter the sample concentration in any way that would result in exhaust samples that are not truly representative of the exhaust stream in question.

Although special procedures and sample modification techniques do exist, these procedures and tactics tend to condition the sample for ease of detection or analysis but may make the sample unrepresentative of the true exhaust composition.

The goal in automobile measurement is, of course, a true representation of the exhaust composition. To achieve this goal and, at the same time, enhance the ability to correctly analyze and time-correlate composition measurements, some form of special conditioning may be required.

The time-correlation problem is probably most severe in this area. In addition to the test instruments and the EPA standard bench having different response times, these respone times tend to vary slightly from test to test for both instrument systems. Thus, under dynamic sample analysis conditions, time-correlation of instrument readings becomes very difficult.

Section 5

DURABILITY TEST

The instruments that successfully passed the laboratory tests and the vehicle exhaust tests and that generally showed results within the manufacturer's specifications were subjected to 3 months of durability testing (or until instrument failure occurred).

5.1 SCOPE

The durability test consisted of cycling the instruments for 50 minutes on undiluted exhaust from an idling gasoline engine, followed by 10 minutes of exposure to outside air. This cycle was conducted for 16 hours a day and then shut down for 8 hours. Tests were conducted 5 days per week and shut down for 2 days. All instrument probes in this test were simultaneously inserted into a common manifold for exhaust sampling.

5.2 SERVICE

Normal servicing as recommended by the manufacturer's literature was performed on each instrument during the durability test. This was done either per the manufacturer's recommendations on maintenance frequency or when immediate attention was required. The scope of this contract between the EPA and Olson Laboratories, Inc., did not provide for any repairs to be performed by Olson Laboratories, Inc., on the instruments that failed during the durability test sequence. This is, of course, exclusive of any required normal service.

5.3 INSTRUMENT FAILURE

Failure in the durability test was defined as either a loss of response of the instrument to exhaust or sample gas, or a significant degradation in the instrument's ability to properly measure specific concentrations of analyzed gases. Additionally, uncontrolled meter variation or loss of stability constituted failure.

Figure 5-1 shows the durability test set up. In the center of the picture is the common exhaust manifold. Behind the manifold is the laboratory test engine. The laboratory technician is seen placing the various instrument probes in the ports of the exhaust manifold. Figure 5-2 shows another view of the common exhaust manifold.

The instruments were rezeroed and spanned each morning before the start of the day's durability test. Zero and span calibrations were performed according to the manufacturer's specifications.

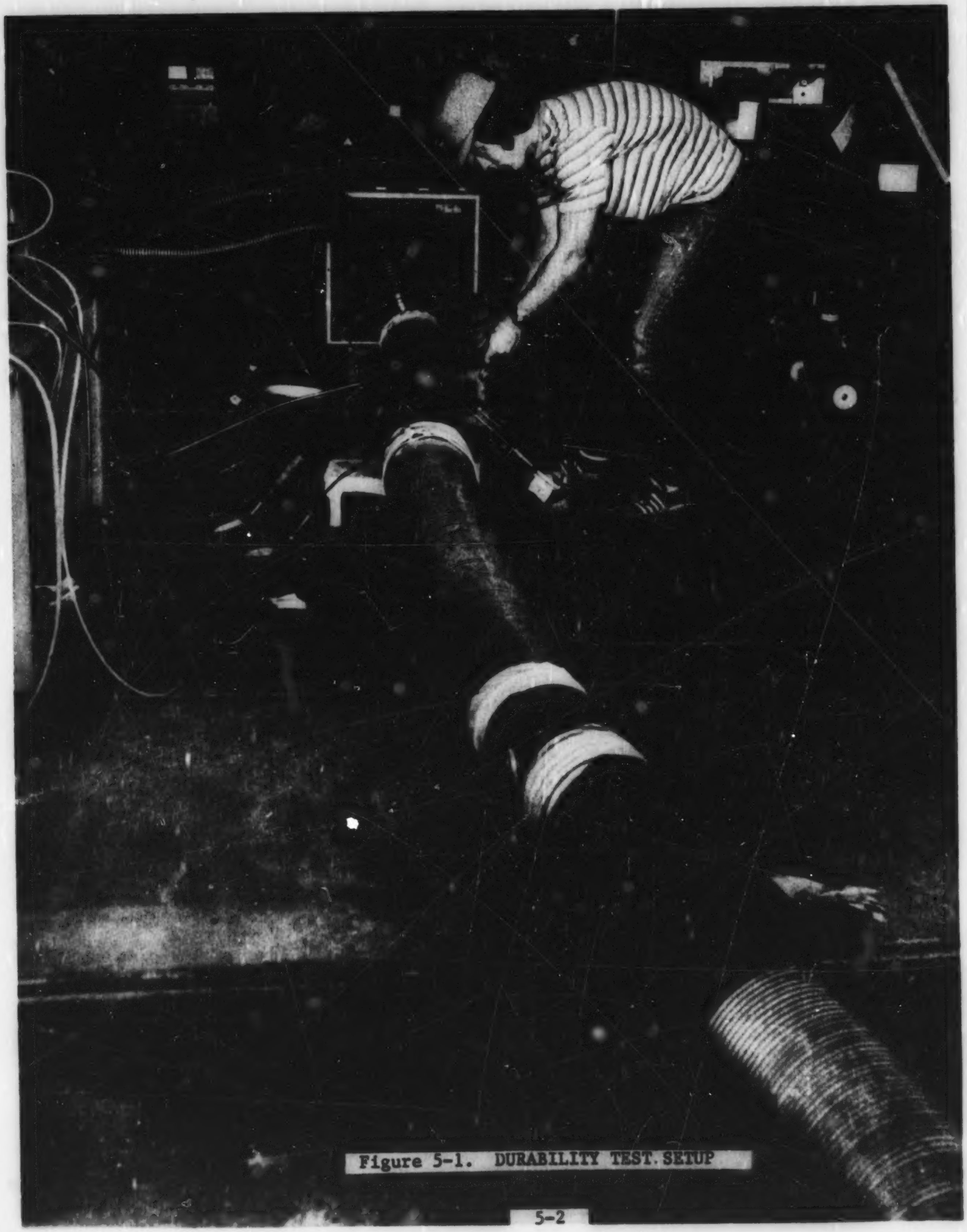

Figure 5-1. DURABILITY TEST SETUP

Figure 5-2. VEHICLE TEST IN PROGRESS

5.4 VIBRATION AND SHOCK TESTS

The instruments were then subjected to a vibration and shock test. This test simulated rolling the instrument over a rough garage floor. The shock test simulates a rolling instrument which collides with a wall or other fixed object.

The test floor was 6 feet by 10 feet expanded metal grating, with diamond shaped openings of approximately 1 inch by 3.75 inches. The test floor grating was elevated 2 inches off of the laboratory floor by utilizing a sub-frame. The test instruments, while operating, were rolled over the grating in the direction of the "short way of the diamond." At the end of the grating, the instruments were rolled off the end and dropped 2 inches to the test floor.

After one traverse of the grating, the instruments were checked for any shift in zero or span setting. Any variation from the previous set points was recorded. If necessary, the instruments were then rezeroed and respanned. Figure 5-3 shows the vibration test in progress.

After zeroing and spanning, the position of the instrument's probe in the common manifold was changed and recorded.

Vibration tests were run only on those instruments that incorporated a cabinet and some form of wheel arrangement for mobility. No attempt was made to run vibration tests on those instruments not equipped with wheels.

The shock transferred to an instrument while rolling along the ground or over rough surfaces is determined by the size and geometry of the instrument's wheels. Since the size and geometry is different for each instrument in question, each instrument's ability to resist shock impact will differ.

It would not be realistic to equip an instrument with a special test cabinet or special test wheels and then run that equipment in the vibration tests. If an instrument was specially equipped by a test laboratory with a test cabinet and wheels, the results of the vibration test might not be indicative of the instrument's ability to resist shock. It might instead be a direct function of the wheel size and geometry.

Where manufacturers have made a decision on wheel size and geometry and have packaged their instrument accordingly, vibration tests are realistic. Where the manufacturer had made no attempt to equip the instrument with wheels, wheel size and geometry selection on the part of the testing agency would be inappropriate and may, in fact, unfairly compare that instrument in these tests.

Normal usage of a nonwheeled instrument would result in the typical level of shock and vibration exposure occurring during pick up and placement operations. Since these instruments were always moved during the durability test, it is felt that the shock and vibration encountered by the nonwheeled instruments is quite representative of the shock and vibration they would see in the real operating environment of a garage or inspection facility.

The performance in the vibration and shock test was reported as the number of days that any span or zero reading varied greater than 3 percent

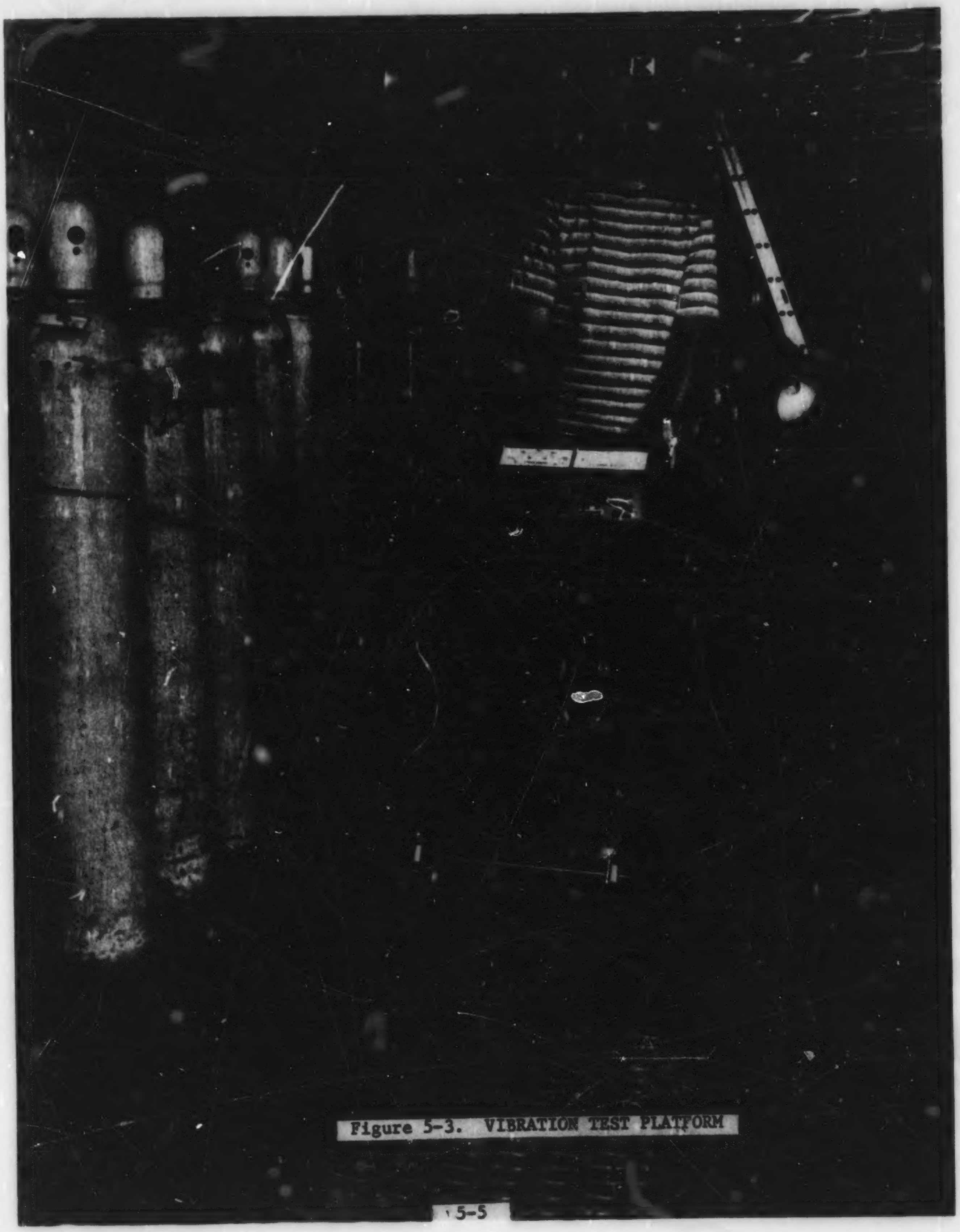

Figure 5-3. VIBRATION TEST PLATFORM

from known calibration gas values, immediately after the test was administered.

5.5 DATA

The data recorded for the durability tests consisted of the number of hours each instrument operated before failing to calibrate, or when the instrument started to display a permanent, obvious malfunction. This data is presented as time to failure in hours.

5.6 EXPOSURE RATING

The typical level of gas concentration for HC, CO and NO experienced by the instruments during durability testing was recorded. This level was recorded as an average value determined by comparing the concentration notations made during each test time period. This data is then converted into an exposure value by combining the concentration level with the time to failure. The data is reported as ppm-hours for HC and NO and percent-hours for CO.

5.7 SERVICE DATA

All incidences of service were recorded by type as follows:

A. Filter change
B. Drain hose
C. Re-zero
D. Repair sample system
E. Other

Each incidence of service was recorded by the technician. The total number of incidences of each service was then normalized by dividing by its time to failure in hundreds of hours.

5.8 DURABILITY SPAN DRIFT

The daily span drift was recorded and the absolute percentage of drift was calculated by comparing it to the span gas concentration.

Section 6

GENERALIZED DATA PRESENTATION AND RATINGS

6.1 OBSERVED PERFORMANCE DATA

Table 6-1 represents a compilation of the most representative data recorded for each instrument during the laboratory tests. This compilation serves as a quick reference to be used when making generalized comparisons of various test instruments. A complete performance data listing for all tests is included in each instrument report section.

6.2 OBJECTIVE RATINGS

Tables 6-2 through 6-16 present an objective performance listing for all instruments based upon their demonstrated performance in the Laboratory, Repeatability, Vehicle and Durability tests. Typical rating placement runs from best performance to worst performance. Normalized rating totals are given for some categories and are presented to allow appreciation of relative ranking with respect to the best performing instrument.

These ratings are presented to be utilized only as a generalized relative performance rating. Specific instrument performance data is included in each instrument report section.

Table 6-1. OBSERVED PERFORMANCE DATA TABLE

INSTRUMENT NAME	RANGE	PROPANE EQUIVALENCE FACTOR (MFGR. STATED)	OBSERVED ACCURACY (WORST READING WITHIN TEMP. OPERATING RANGE) SEA LEVEL		STABILITY LOW RANGE (ZERO DRIFT) WORST CASE CYCLE 1 THRU 4	REPEATABILITY %FS	RESPONSE TIME IN SEC. 90% OF GAS CONCENTRATION	WARM UP TIME (MINUTES)			INTERFERENCE (≥1% FS)	INPUT POWER SENSITIVITY ±10% NOM. VOLTAGE %FS HIGH RANGE	SKILL REQUIREMENT
			HIGH SCALE %FS	LOW SCALE %FS				35°F	70°F AVERAGE OF CYCLE 1 & 4	110°F			
HORIBA MEXA 300A	0-400/2000 PPM 0-2%/10%	0.52	HC-2.4 CO-3.0	HC-2.25 CO-5.0	HC-2.5%FS CO-0	HC-2.54 CO-3.9	HC-11.1 CO-9.9	HC-29 CO-29	HC-10.75 CO-10.75	HC-10 CO-10	CO_2/N_2, HC/N_2 CO/N_2, H_2O/AIR NO/N_2, O_2/N_2	0	LOW
BARNES 8335 C	0-400/2000 PPM 0-2%/10%	0.53	HC-2.05 CO-3.0	HC-2.5 CO-5.0	HC-1.25%FS CO-2.5%FS	HC-2.0 CO-4.75	HC-13.6 CO-13.1	HC-26 CO-26	HC-10 CO-9.5	HC-13 CO-13	CO_2/N_2, HC/N_2 CO/N_2, H_2O/AIR	0.5	LOW
SCOTT 3C	0-300/2000 PPM 0-.5%/10%	0.499	HC-3.3 CO-3.0	HC-4.0 CO-2.0	HC-9.33%FS CO-70%FS*	HC-2.03 CO-2.35	HC-13.6 CO-12.6	HC-21 CO-21	HC-16.5 CO-15.5	HC-12 CO-11	CO_2/N_2 HC/N_2 NO/N_2	0.5	LOW
MARQUETTE 42-159	0-1000/2000 PPM 0-3000 PPM 0-5%/10%	0.51	HC-3.25 CO-1.5	HC-6.4 CO-4.8	HC-3.0%FS CO-1%FS	HC-4.49 CO-2.9	HC-18.1 CO-16.3	HC-27 CO-27	HC-19 CO-16	HC-14 CO-14	NO INTERFERENCE	1.0	LOW
BECKMAN 590	0-400/2000 PPM 0-2%/10%	0.53	HC-2.7 CO-2.0	HC-2.25 CO-3.0	HC-15%FS CO-3%FS	HC-4.44 CO-3.38	HC-10.5 CO-11.6	HC-25 CO-25	HC-17 CO-17	HC-11 CO-11	CO_2/N_2 HC/N_2 CO/N_2	0.2	LOW
STEWART WARNER 3161	0-500/2000 PPM 0-2.5%/10%	0.52	HC-3.4 CO-3.0	HC-3.4 CO-16.0	HC-1.2%FS CO-1.2%FS	MALFUNCTION	HC-11.8 CO-11.9	HC-21 CO-21	HC-8.5 CO-8.5	HC-10 CO-10	CO_2/N_2 HC/N_2, CO/N_2 NO/N_2	1.0	LOW
SUN EPA 75	0-500/2000 PPM 0-2.5%/10%	0.518	HC-1.25 CO-1.0	HC-1.0 CO-4.0	HC-1%FS CO-0	HC-2.88 CO-3.18	HC-13.3 CO-12.8	HC-24 CO-24	HC-10.5 CO-10.5	HC-12 CO-12	CO_2/N_2 CO/N_2 O_2/N_2	1.0	LOW
MOPAR 3C	0-300/2000 PPM 0-0.5%/10%	0.493	HC-1.75 CO-3.0	HC-3.33 CO-4.2	HC-4%FS CO-80%FS*	HC-2.71 CO-2.15	HC-8.8 CO-8.3	HC-22 CO-22	HC-17.5 CO-15.5	HC-12 CO-12	CO_2/N_2, HC/N_2 NO/N_2, O_2/N_2	0	LOW
SEARS 713-21022	0-500/2000 PPM 0-2.5%/10%	—	MALFUNCTION		HC-5%FS CO-2%FS	MALFUNCTION	HC- (NO CO- DATA)	HC- (NO CO- DATA)	HC-10 CO-10 CYCLE 1 ONLY	HC- (NO CO- DATA)	CO/N_2 CYCLES 2,3,4 MALFUNCTION	NO DATA	LOW
KAL-EQUIP 4094D	0-500/2000 PPM 0-2.5%/10%	0.56	HC-3.9 CO-2.0	HC-4.8 CO-10.0	HC-2.4%FS CO-0.8%FS	HC-7.12 CO-7.47	HC-33.1 CO-31.5	HC-19 CO-19	HC-6.5 CO-6.5	HC-9 CO-7	CO_2/N_2, HC/N_2 CO/N_2, NO/N_2	1.0	LOW
PULSAR 660	0-400/2000 PPM 0-2%/10%	0.45	HC-5.15 CO-3.0	HC-5.5 CO-5.5	HC-10%FS CO-5%FS	HC-3.49 CO-5.5	HC-16.8 CO-14.1	HC-20 CO-20	HC-9 CO-7.5	HC-10 CO-8	CO/N_2, NO/N_2	0.5	LOW
AUTOSCAN 710C	0-500/2000 PPM 0-2%/10%	0.493	HC-2.75 CO-3.2	HC-2.4 CO-4.5	HC-1.2%FS CO-0.5%FS	HC-3.16 CO-5.0	HC-17.8 CO-17.0	HC-23 CO-23	HC-9 CO-10 CYCLE 4 ONLY	HC-11 CO-9.5	H_2O/AIR CYCLES 1,2 MALFUNCTION	1.0	LOW
ALLEN 23-160 CA	0-500/2000 PPM 0-2.5%/10%	0.52	HC-14.1 CO-9.7	HC-16.0 CO-6.4	HC-18%FS CO-2%FS	HC-4.03 CO-4.53	HC-14.0 CO-13.5	HC-40 CO-40	HC-10.75 CO-9	HC-15 CO-15	NO INTERFERENCE	0.55	LOW
AUTOSENSE 200	0-2000 PPM 0-10%	0.596	HC-4.95 CO-3.2	NO LOW SCALE	HC-0.5%FS CO-0	HC-4.08 CO-2.05	HC-42.0 CO-21.3	HC-15 CO-15	HC-7.5 CO-7.5	HC-7 CO-7	NO INTERFERENCE	NO DATA	LOW
HORIBA MEXA 240	0-1000 PPM 0-4000 PPM	—	NO-0.75	NO-1.6	NO-0.6%FS	NO-1.41	NO-13.6	NO-14	NO-6	NO-5	CO_2/N_2 HC/N_2 CO/N_2	0	LOW
THERMO ELECTRON 8A	0-500 PPM 0-1000 PPM 0-5000 PPM	—	NO-7.0 MED. NO-4.34	NO-1.2	NO-1.0%FS	NO-15.5	NO-44.9	NO-22	NO-13.5	NO-20	NO INTERFERENCE CYCLE 2 MALFUNCTION	1.0	MEDIUM
IBC N322	0-500 PPM 0-1000 PPM 0-5000 PPM	—	NO-0.6 NO-2.5	NO-1.2	NO-1.0%FS	NO-3.25	NO-10.1	NO-21	NO-8.5	NO-9	CO/N_2	NO DATA	MEDIUM TO HIGH

*CO Range - 0.5% F.S.

Table 6-2.
WARMUP TIME: (TEMPERATURE AND HUMIDITY - QUICKEST WARMUP TIME TO SLOWEST)

	HC/CO Cycle 1	HC/CO Cycle 2	HC/CO Cycle 3	HC/CO Cycle 4	OVERALL HC/CO
1.	Barnes } tie	Autosense	Autosense	Kal Equip } tie	Kal Equip
2.	Kal Equip }	Kal Equip	Kal Equip	Pulsar }	Autosense
3.	Stewart Warner } tie	Horiba }	Pulsar	Autosense	Stewart Warner
4.	Autosense }	Stewart Warner } tie	Scott } tie	Stewart Warner } tie	Pulsar
5.	Horiba }	Pulsar }	Stewart Warner }	Sun }	Horiba } tie
6.	Allen } tie	Beckman } tie	Mopar	Autoscan	Sun }
7.	Sears }	Autoscan }	Autoscan	Beckman	Barnes
8.	Sun } tie	Scott }	Sun	Horiba } tie	Autoscan
9.	Pulsar }	Sun } tie	Beckman	Allen }	Beckman
10.	Scott } tie	Mopar }	Barnes	Barnes	Scott
11.	Mopar }	Barnes	Marquette	Scott } tie	Mopar
12.	Marquette } tie	Marquette	Horiba	Marquette }	Allen
13.	Beckman }	Allen	Allen	Mopar	Marquette
14.	Autoscan	Sears	Sears	Sears	Sears

	NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO OVERALL
1.	Horiba	Horiba	Horiba	Horiba	Horiba
2.	IBC	IBC	IBC	IBC	IBC
3.	Thermo Elec Electron	Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron

Table 6-3.
ZERO DRIFT (TEMPERATURE & HUMIDITY)

	HC/CO Cycle 1	HC/CO Cycle 2	HC/CO Cycle 3	HC/CO Cycle 4	HC/CO Overall
1.	Horiba }	Stewart Warner	Sun	Horiba } tie	Horiba
2.	Sun }	Marquette	Autosense	Autosense }	Kal Equip
3.	Mopar } tie	Kal Equip	Kal Equip	Marquette	Stewart Warner
4.	Allen }	Horiba	Autoscan	Kal Equip	Autosense } tie
5.	Marquette } tie	Pulsar	Stewart Warner	Barnes	Marquette }
6.	Autosense }	Beckman	Horiba }	Stewart Warner	Sun
7.	Stewart Warner } tie	Allen	Barnes } tie	Beckman }	Allen
8.	Kal Equip }	Scott	Beckman }	Sun } tie	Beckman
9.	Barnes	Mopar	Pulsar }	Autoscan	Barnes
10.	Scott	Barnes }	Marquette	Pulsar	Pulsar
11.	Beckman } tie	Sun }	Allen	Allen	Mopar
12.	Pulsar }	Sears } tie	Mopar	Mopar	Autoscan
13.	Sears	Autoscan }	Scott	Scott	Scott
14.	Autoscan	Autosense }	Sears	Sears	Sears

	NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO Overall
1.	Horiba	Horiba	Horiba	Horiba	Horiba
2.	Thermo Electron } tie	IBC	Thermo Electron	Thermo Electron	Thermo Electron
3.	IBC }	Thermo Electron	IBC	IBC	IBC

Table 6-4.
ACCURACY DETERMINATION (TEMPERATURE & HUMIDITY) - (MOST ACCURATE TO LEAST ACCURATE)

OVERALL ACCURACY RATING

	HC-High Overall	HC-Low Overall	CO-High Overall	CO-Low Overall	HC/CO Overall	Normalized Rating Total
1.	Horiba	Allen	Marquette	Scott	Horiba	1.0
2.	Mopar	Horiba	Horiba	Marquette	Marquette	1.5
3.	Marquette	Sun ⎫ tie	Kal Equip	Autosense	Beckman	2.05
4.	Scott	Autosense ⎭	Beckman	Beckman	Sun	2.25
5.	Barnes	Mopar ⎫ tie	Sun	Horiba	Mopar ⎫ tie	2.35
6.	Sun	Beckman ⎭	Pulsar	Mopar	Scott ⎭	2.35
7.	Beckman	Barnes	Barnes	Pulsar	Allen	2.8
8.	Allen	Pulsar	Allen	Sun	Barnes	2.9
9.	Pulsar	Scott ⎫ tie	Scott	Stewart Warner	Pulsar	3.0
10.	Stewart Warner	Marquette ⎭	Mopar	Barnes	Autosense	3.15
11.	Kal Equip	Stewart Warner	Stewart Warner	Allen	Kal Equip	3.9
12.	Autoscan	Kal Equip	Autosense	Autoscan	Stewart Warner	4.1
13.	Autosense	Autoscan	Autoscan	Kal Equip	Autoscan	5.0
14.	Sears	Sears	Sears	Sears	Sears	5.6

Table 6-5
ACCURACY DETERMINATION (TEMPERATURE & HUMIDITY) - (MOST ACCURATE TO LEAST ACCURATE)

HIGH RANGE NO

	NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO High Range Overall
1.	Horiba	Horiba	Horiba	Horiba	Horiba
2.	Thermo Electron	IBC	IBC	Thermo Electron	Thermo Electron } tie
3.	IBC	Thermo Electron (malfunction)	Thermo Electron	IBC	IBC }

LOW RANGE NO

	NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 3	NO Low Range Overall
1.	Horiba } tie	Horiba	IBC	Horiba	Horiba
2.	Thermo Electron }	IBC	Thermo Electron	Thermo Electron	Thermo Electron } tie
3.	IBC	Thermo Electron (malfunction)	Horiba	IBC	IBC }

OVERALL ACCURACY RATINGS

	NO High Range Overall	NO Low Range Overall	NO Overall
1.	Horiba	Horiba	Horiba
2.	Thermo Electron } tie	Thermo Electron } tie	Thermo Electron } tie
3.	IBC }	IBC }	IBC }

Table 6-6.
ACCURACY DETERMINATION - HIGH ALTITUDE

	HC High	HC Low	CO High	CO Low	HC/CO Overall
1.	Marquette	Autosense	Kal Equip	Marquette	Marquette
2.	Sun	Horiba } tie	Marquette } tie	Autosense	Autoscan
3.	Mopar } tie	Sun }	Autoscan }	Mopar	Autosense
4.	Autoscan }	Autoscan }	Barnes } tie	Pulsar	Sun
5.	Barnes } tie	Barnes	Autosense }	Horiba	Barnes
6.	Beckman }	Stewart Warner	Stewart Warner	Sun	Horiba
7.	Horiba	Beckman	Sun	Autoscan	Mopar
8.	Allen	Mopar	Allen	Barnes	Stewart Warner
9.	Stewart Warner	Pulsar	Pulsar	Stewart Warner } tie	Kal Equip
0.	Autosense	Marquette	Sears	Allen }	Pulsar
1.	Kal Equip	Kal Equip } tie	Horiba	Kal Equip	Allen
2.	Scott	Allen }	Scott } tie	Sears	Beckman
3.	Pulsar	Scott	Mopar }	Scott	Scott
4.	Sears	Sears	Beckman (malfunction)	Beckman (malfunction)	Sears

	NO High	NO Low	NO Overall
1.	Horiba	Horiba } tie	Horiba
2.	IBC	Thermo Electron }	Thermo Electron
3.	Thermo Electron	IBC	IBC

Table 6-7.
RESPONSE & RECOVERY (TEMPERATURE & HUMIDITY CYCLES) - (QUICKEST TO SLOWEST)

	HC/CO Cycle 1	HC/CO Cycle 2	HC/CO Cycle 3	HC/CO Cycle 4	HC/CO Overall
1.	Beckman	Horiba	Horiba	Scott	Scott
2.	Scott	Beckman	Mopar	Mopar	Beckman
3.	Mopar	Allen	Sun	Beckman	Mopar } tie
4.	Horiba	Scott	Scott	Pulsar	Horiba
5.	Allen	Mopar	Allen	Barnes	Allen
6.	Sun	Marquette	Beckman	Allen	Pulsar
7.	Barnes	Pulsar	Pulsar	Sun	Sun
8.	Marquette	Kal Equip	Autoscan	Horiba	Barnes
9.	Pulsar	Stewart Warner	Barnes	Autoscan	Marquette
10.	Sears	Barnes	Marquette	Marquette	Kal Equip
11.	Kal Equip	Sun	Stewart Warner	Kal Equip	Autoscan
12.	Stewart Warner	Sears } tie	Kal Equip } tie	Autosense	Stewart Warner
13.	Autosense	Autoscan	Autosense	Stewart Warner	Autosense
14.	Autoscan (malfunction)	Autosense	Sears	Sears	Sears

	NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO Overall
1.	IBC	IBC	Horiba	IBC	
2.	Horiba	Horiba	IBC	Horiba	
3.	Thermo Electron	Thermo Electron (malfunction)	Thermo Electron	Thermo Electron	

Table 6-8.
GAS INTERFERENCE LABORATORY TESTS
(LEAST RESPONSE TO MOST RESPONSE)

HC/CO Overall (All 6 Gases)		Normalized Rating Total	NO Overall (All 6 Gases)	Normalized Rating Total
Autosense		1	Thermo Electron	1
Marquette		1.14	IBC	1.34
Autoscan		1.34	Horiba	1.73
Mopar		1.37		
Barnes		1.39		
Scott		1.42		
Allen		1.43		
Pulsar		1.44		
Horiba		1.47		
Sun		1.58		
Beckman		1.73		
Kal Equip		1.96		
Sears	tie	2.96		
Stewart Warner		2.96		

Table 6-9.

VOLTAGE PROFILE (LEAST INFLUENCED TO MOST INFLUENCED)

<table>
<tr><th></th><th>HC + 10%</th><th></th><th>HC - 10%</th><th></th><th>CO + 10%</th><th></th><th>CO - 10%</th><th></th><th>HC/CO Overall</th><th></th></tr>
<tr><td>1.</td><td>Horiba</td><td rowspan="6">tie</td><td>Horiba</td><td rowspan="6">tie</td><td>Horiba</td><td rowspan="7">tie</td><td>Horiba</td><td rowspan="7">tie</td><td>Horiba</td><td rowspan="2">tie</td></tr>
<tr><td>2.</td><td>Barnes</td><td>Barnes</td><td>Scott</td><td>Barnes</td><td>Mopar</td></tr>
<tr><td>3.</td><td>Beckman</td><td>Scott</td><td>Beckman</td><td>Scott</td><td>Beckman</td><td></td></tr>
<tr><td>4.</td><td>Mopar</td><td>Beckman</td><td>Mopar</td><td>Mopar</td><td>Barnes</td><td></td></tr>
<tr><td>5.</td><td>Pulsar</td><td>Mopar</td><td>Autoscan</td><td>Pulsar</td><td>Scott</td><td></td></tr>
<tr><td>6.</td><td>Allen</td><td>Autoscan</td><td>Allen</td><td>Allen</td><td>Allen</td><td></td></tr>
<tr><td>7.</td><td>Kal Equip</td><td></td><td>Kal Equip</td><td></td><td>Autosense</td><td>Autosense</td><td>Pulsar</td><td></td></tr>
<tr><td>8.</td><td>Sun</td><td></td><td>Sun</td><td rowspan="2">tie</td><td>Barnes</td><td rowspan="2">tie</td><td>Beckman</td><td></td><td>Autoscan</td><td></td></tr>
<tr><td>9.</td><td>Autoscan</td><td></td><td>Pulsar</td><td>Pulsar</td><td>Marquette</td><td rowspan="5">tie</td><td>Sun</td><td></td></tr>
<tr><td>10.</td><td>Scott</td><td></td><td>Stewart Warner</td><td></td><td>Marquette</td><td></td><td>Stewart Warner</td><td>Autosense</td><td></td></tr>
<tr><td>11.</td><td>Marquette</td><td></td><td>Allen</td><td></td><td>Stewart Warner</td><td></td><td>Sun</td><td>Kal Equip</td><td></td></tr>
<tr><td>12.</td><td>Stewart Warner</td><td></td><td>Marquette</td><td></td><td>Sun</td><td></td><td>Kal Equip</td><td>Marquette</td><td rowspan="2">tie</td></tr>
<tr><td>13.</td><td>Sears</td><td rowspan="2">tie</td><td>Sears</td><td rowspan="2">tie</td><td>Kal Equip</td><td></td><td>Autoscan</td><td>Stewart Warner</td></tr>
<tr><td>14.</td><td>Autosense</td><td>Autosense</td><td>Sears (malfunction)</td><td></td><td>Sears (malfunction)</td><td></td><td>Sears</td><td></td></tr>
</table>

	NO + 10%	NO - 10%	NO Overall
1.	Horiba	Horiba	Horiba
2.	IBC	IBC	IBC
3.	Thermo Electron (malfunction)	Thermo Electron (malfunction)	Thermo Electron

Table 6-10.
VEHICLE TESTS ACCURACY
(MOST ACCURATE TO LEAST ACCURATE)
OVERALL ACCURACY RATING

HC/CO Overall (All 3 Modes)		Normalized Rating Total
Autoscan		1
Marquette		1.15
Horiba		1.39
Beckman		1.52
Allen		1.54
Scott		1.57
Sun		1.89
Pulsar		2.02
Barnes		2.13
Mopar		2.16
Kal Equip		2.39
Stewart Warner		2.98
Sears	tie	3.8
Autosense		3.8

Table 6-11.
VEHICLE TESTS ACCURACY
(MOST ACCURATE TO LEAST ACCURATE)
(STANDARD MODE)

NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO Overall	Normalized % Rate
Horiba	Horiba	Horiba	Horiba	Horiba	1
IBC	IBC	IBC	IBC	IBC	2
Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	3

(LEAN MODE)

NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO Overall	Normalized % Rate
IBC	Horiba	Horiba	Horiba	Horiba	1
Horiba	IBC	IBC	IBC	IBC	1.4
Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	2.4

(RICH MODE)

NO Cycle 1	NO Cycle 2	NO Cycle 3	NO Cycle 4	NO Overall	Normalized % Rate
Horiba	Horiba	Horiba	Horiba	Horiba	1
IBC	IBC	IBC	IBC	IBC	2
Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	Thermo Electron	3

Table 6-12.
DIAGNOSTIC VEHICLE TESTS
(MOST ACCURATE TO LEAST ACCURATE)

Ignition Retard		Sparkplug Shorted		Ignition Advance	
HC	CO	HC	CO	HC	CO
Autosense	Horiba	Sun	Autoscan	Beckman	Autoscan
Autoscan	Autoscan	Mopar	Autosense	Scott	Horiba
Marquette	Autosense	Allen	Horiba	Autosense	Allen
Mopar	Allen	Autoscan	Allen	Autoscan	Autosense
Allen	Mopar	Scott	Pulsar	Allen	Mopar
Kal Equip	Scott	Autosense	Mopar	Marquette	Pulsar
	Sun Pulsar	Beckman		Stewart Warner	Scott
Beckmen		Stewart Warner	Sun		
	Stewart Warner	Kal Equip		Sun	Stewart Warner
Stewart Warner	Beckman		Scott	Pulsar	Sun
Horiba Pulsar	Marquette	Horiba	Stewart Warner	Horiba	Beckman
			Beckman	Kal Equip	Marquette
Sun	Kal Equip	Marquette	Marquette	Mopar	Kal Equip
Scott	Sears Barnes tie	Pulsar	Kal Equip	Sears Barnes tie	Sears Barnes tie
Barnes Sears tie		Sears Barnes tie	Sears Barnes tie		

Table 6-13.
DIAGNOSTIC VEHICLE TESTS
(MOST ACCURATE TO LEAST ACCURATE)

Ignition Retard	Sparkplug Shorted	Ignition Advance
NO	NO	NO
Horiba	Horiba	Horiba
IBC	IBC	IBC
Thermo Electron	Thermo Electron	Thermo Electron

Table 6-14.
DURABILITY TESTS

(LEAST DRIFT TO MOST DRIFT)		(MOST HRS. TO LEAST HRS. 960 HRS. MAXIMUM)	(LOWEST RATE TO HIGHEST RATE)	(LEAST SERVICE TO MOST SERVICE)
AVERAGE DAILY SPAN DRIFT		HOURS OPERATION	SHOCK FAILURE RATE	TOTAL SERVICE
HC	CO	HC/CO	HC/CO	
Beckman	Beckman	Scott } tie	Beckman	Scott
Scott	Mopar	Marquette }	Sun	Autoscan
Autoscan	Scott	Mopar	Scott	Mopar
Mopar	Autosense	Autosense	Mopar	Barnes
Sun	Sun	Allen	Allen	Sun
Allen	Autoscan	Pulsar	Horiba	Pulsar
Autosense	Horiba	Stewart Warner	Marquette	Beckman
Marquette	Marquette	Horiba	Autoscan	Autosense
Horiba	Allen	Autoscan	Stewart Warner	Allen
Kal-Equip	Pulsar	Kal-Equip	Pulsar	Stewart Warner
Pulsar	Kal-Equip	Sun	Autosense	Kal-Equip
Barnes } tie	Stewart Warner	Beckman	Barnes	Horiba
Sears }	Sears Barnes } tie	Barnes		Sears
NO		NO		NO
Horiba		Horiba		IBC
IBC		IBC		Horiba
Thermo Electron		Thermo Electron		Thermo Electron

* Sears, Kal-Equip and all the NO instruments (IBC, Thermo Electron and Horiba) had stationary packages and therefore were not tested for vibration and shock.

Table 6-15.

INSTRUMENT SERVICE REQUIREMENTS

A CHANGE FILTER (PER 100 HRS.)	B DRAIN HOSE (PER 100 HRS.)	C REZERO (PER 100 HRS.)	D SAMPLING SYST. (PER 100 HRS.)	E OTHER (PER 100 HRS.)
BARNES SCOTT MOPAR PULSAR tie	SUN KAL-EQUIP AUTOSCAN tie	BARNES SCOTT BECKMAN SUN MOPAR PULSAR AUTOSCAN tie	BARNES SCOTT BECKMAN MOPAR PULSAR AUTOSCAN AUTOSENSE tie	BARNES HORIBA SCOTT BECKMAN SUN MOPAR AUTOSCAN ALLEN tie
MARQUETTE	STEWART WARNER	AUTOSENSE	ALLEN	PULSAR
STEWART WARNER	AUTOSENSE	ALLEN	HORIBA	AUTOSENSE
SUN	SCOTT	STEWART WARNER	SUN	STEWART WARNER
AUTOSCAN	MARQUETTE	KAL-EQUIP	KAL-EQUIP	KAL-EQUIP
ALLEN	ALLEN	HORIBA MARQUETTE tie	STEWART WARNER MARQUETTE tie	SEARS
AUTOSENSE	BECKMAN	SEARS	SEARS	
KAL-EQUIP	MOPAR BARNES tie			
SEARS	PULSAR HORIBA tie			
	SEARS			

NO INSTRUMENTS

IBC HORIBA THERMO ELECTRON	IBC HORIBA tie THERMO ELECTRON	IBC HORIBA THERMO ELECTRON	IBC HORIBA tie THERMO ELECTRON	IBC HORIBA THERMO ELECTRON

Table 6-16.
DURABILITY TESTS
(LIFE, SPAN DRIFT, SERVICE AND SHOCK FAILURE PARAMETERS)

OVERALL PERFORMANCE (ALL 4 PARAMETERS EQUALLY WEIGHTED)		NORMALIZED RATE TOTAL
SCOTT		1
MOPAR		1.52
BECKMAN		2.10
AUTOSCAN	tie	2.67
SUN		2.67
ALLEN	tie	3.24
AUTOSENSE		3.24
MARQUETTE		3.48
HORIBA		4.10
PULSAR		4.19
STEWART WARNER		4.57
BARNES		5.33
KAL EQUIP		5.38
SEARS		6.52

Section 7

INDIVIDUAL INSTRUMENT REPORTS

The following sections in this report contains 17 "Mini Reports," each concerned with a specific instrument.

The "Mini Reports" present a detailed physical description of each instrument covering electronics, displays, control panels, construction, sample systems, theory of operation, and other pertinent information necessary to fully describe and understand each unit. A subjective operational performance evaluation is presented along with a general data review with comments. Each report includes a complete composite of all test data collected for each instrument during the tests. An explanation of the data presentation and the respective tests is contained in Sections 3, 4 and 5 of this report. Following the "Mini Report" data presentation, are appropriate instrument photographs depicting instrument configuration and sample probe design.

7.1 HORIBA MEXA 300A

Manufacturer - Horiba Instruments, Inc.

Description - HC/CO exhaust analyzer configured as a bench top analyzer incorporating an optional four-wheel mobile cart. The cart has a built-in gas calibration system. Incorporates readout of both HC and CO on separate meters.

Dimensions -

Analyzer: Weight - 43 lbs.
Height - 12-1/2 inches
Width - 21 inches
Depth - 16-1/2 inches

Cart: Weight - 63 lbs.
Height - 31 inches
Width - 24 inches
Depth - 16-1/2 inches

The cart holds gas calibration equipment and incorporates additional read access storage space.

Material of Construction - Main analyzer cabinet and cart - heavy walled plastic molding with sheet metal on analyzer face, cart front and shelves.

Color - Red with silver front panels.

Mobility - Four, 4-inch wheels; two at front corners stationary, two at rear corners rotate for steering. The two rear wheels incorporate wheel locks.

Accessories - Tail pipe probe, flexible 24-foot sample hose, particulate filters, water separator.

Control Package -

Front Access - Mode select switch (five-position)
1. Standby
2. Sample (with indicator light)
3. Zero
4. Span check
5. Calibration gas
HC - zero knob
HC - span knob
HC - high range adjustment (screw)
CO - zero knob
CO - span knob
CO - high range adjustment (screw)
ON/OFF - toggle switch with indicator light
Range select toggle switch with high range
Indicator light
Flow alarm light
2 amp fuse cartridge

Cart Control Panel - Push button calibration gas valve. Calibration gas cylinder pressure gauge.

Meters - Dual 8", 90° swing. Black figures on white background.

Ranges - HC - 2000 ppm in 50 ppm increments
400 ppm in 10 ppm increments
CO - 10% in 0.10% increments
2% in 0.05% increments

The HC meter showed sensitivity to static electricity. (Needle moved up-scale and sticks when cloth brushed against meter face.) This indicates the need for the use of an antistatic coating on the HC meter cover. The CO meter showed no sensitivity to static electricity. Meter visibility and readability is rated as good.

Altitude Compensation - Internal electronic (no manual reset)

Probe - Braided flexible tube with perforated hard tube tip, hard tube extension to plastic handle.

Filters and Sample Handling - Water trap with paper filter cartridge, particulate "cigarette filter" cartridges for sample and drain.

Cal Gas Inlet - Rear of analyzer.

Power Requirements - 115 VAC (60HZ) 150VA

Operating Principles - Dual beam nondispersive infrared with chopper. Luft-type, gas-charged detectors, positive filter, parallel cell hot wire sources.

Calibration - Electro-mechanical with swinging arm span checker. Provisions are incorporated for gas calibration (both internal and external).

Operation and Calibration - Straightforward, explanation included in operator's manual.

1. Power up and warm up
2. Zero set
3. Gas calibration
4. Test

(Electro-mechanical span check applicable after initial gas calibration.)

7.1.1 Operational Performance Comments

In general, this unit was easy to use and easy to calibrate. The mobility of the cart was good and the locking feature on the rear wheels worked well. The display showed good response and stability. Calibration pot adjustment was fine enough to afford easy meter setting. The rear panel incorporated four ports (vent, air/ext gas, cal gas, drain). Gas calibration using these ports posed no severe problem, although the nomenclature, air/ext gas and cal gas, was moderately confusing.

The sample handling system presented the only real problem encountered with this instrument. Under durability test conditions, the paper filter in the external water trap repeatedly became wet causing the restricted flow indication light to come on. With the condition of reduced flow, the sample hose quickly filled with water. This problem may be compounded by the uphill routing of the sample aspirator outlet. In addition, the filter tip in the aspirator outlet may have contributed to this problem. The maintenance required by this problem consisted of changing the paper filter in the aspirator and draining the sample hose.

In the laboratory tests, this instrument showed reasonable warm up times under all temperature conditions. The zero drift for all temperature conditions showed the best performance of all instruments. In accuracy determination, the Horiba high and low range HC showed the best combined performance. High range CO was second best of all instruments, low range CO was fifth best. Overall, the Horiba showed the best sample gas accuracy of all HC/CO instruments. In high altitude performance, the overall Horiba accuracy was sixth best, indicating an apparent accuracy degradation with altitude.

At normal laboratory temperature, the unit showed essentially no response to interference gases. Both high and low temperature extremes produced significant interference response from various gases. The Horiba showed no HC response to acetylene, benzene or ethylene. The unit was most responsive to isobutylene, followed by toluene and methane.

The Horiba unit was not sensitive to input voltage variation. Instrument repeatability was rated good and quite acceptable for I/M application.

The Horiba analyzer was rated third best overall in the vehicle tests. Actual percentage errors in exhaust analysis were sometimes quite high. Response time variation may have contributed to this problem. As in the vehicle test, the percentage error values achieved by the Horiba in the diagnostic test were quite high but, overall, the unit correlated third best of all instruments with the EPA Bench.

In the durability test the Horiba ran 272 hours out of a total of 960 hours. This corresponded to an HC exposure of 257,040 ppm-hours and CO exposure of 443 percent-hours. The instrument failed because the HC scale could not be zeroed after prolonged exposure to exhaust gases.

This problem occurred gradually and crept up for several days. The unit would exhibit fairly good recovery early in a test day but by midafternoon, the HC reading on air would begin to climb. Failure was identified when the HC indicator remained up-scale and could not be brought down within acceptable limits. During the durability test, the Horiba failed the shock and vibration test only two times. Both failures occurred on the HC zero mode. This is a failure rate of 0.12 failures per day and indicates that the instrument has very good resistance to shock. Average daily span drift of this instrument measured from test-day to test-day was 5.75 percent for HC and 4.54 percent for CO. This was an acceptable value but it indicates that span adjustment is required more frequently than on a daily basis.

The Horiba required a total of 54 filter changes (19.9 per 100 hours) during the durability test, and the sample hose required draining 71 times (26 per 100 hours). Compared to the other units, this unit required significantly more maintenance to continue proper operation.

The tail pipe probe supplied with this unit showed no significant deterioration at the end of testing.

Other than the high system maintenance requirement, this unit demonstrated good performance with no problems or breakdowns until the final durability test.

Test data for Horiba Mexa 300A Infrared Exhaust Analyzer are shown in Tables 7-1 through 7-5.

Photographs of the instrument are shown in Figures 7-1, 7-2, and 7-3.

Attachment (1)

Table 7-1. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: HORIBA MEXA 300A

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	9	10	29	12.5
	LOW	CO	9	10	29	12.5

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	0	2.5	2.5	0
	LOW	CO	0	0	0	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.75		0.25	0	1.25	0.5
	LOW	CO	0	0	-	0	0	0.5

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 0.14	+ 0.15	+ 0.81	+ 0.30
	HIGH	HC/CO	70	- 1.41	- 1.00	+ 3.08	+ 2.0
	HIGH	HC/CO	100	- 0.11	- 0.10	+ 0.11	+ 0.1
	LOW	HC/CO	35	- 0.95	- 0.25	+10.15	+ 3.5
	LOW	HC/CO	70	+ 1.23	+ 0.75	+ 0.95	+ 0.5
	LOW	HC/CO	100	+ 1.37	+ 1.25	- 2.25	- 2.0
CYCLE 2	HIGH	HC/CO	35	+ 1.74	+ 0.60	- 1.88	- 0.70
	HIGH	HC/CO	70	- 3.39	- 2.4	+ 1.54	+ 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	+ 3.26	+ 3.00
	LOW	HC/CO	35	- 2.86	- 0.75	+ 4.35	+ 1.5
	LOW	HC/CO	70	+ 0.41	+ 0.25	0	0
	LOW	HC/CO	100	0	0	0	0

Table 7-1. DATA COMPOSITE - LABORATORY TEST (Cont'd)

HORIBA MEXA 300A

CYCLE 3	HIGH	HC/CO	35	+ 1.74	+ 0.60	+ 1.61	+ 0.60
	HIGH	HC/CO	70	- 1.98	- 1.40	+ 1.54	+ 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	0	0
	LOW	HC/CO	35	- 2.86	- 0.75	+ 1.45	+ 0.50
	LOW	HC/CO	70	- 1.64	- 1.00	- 0.95	- 0.50
	LOW	HC/CO	100	+ 1.65	+ 1.50	- 1.71	- 1.50
CYCLE 4	HIGH	HC/CO	35	+ 0.29	+ 0.10	- 1.88	- 0.70
	HIGH	HC/CO	70	- 2.33	- 1.65	0	0
	HIGH	HC/CO	100	+ 0.66	+ 0.05	0	0
	LOW	HC/CO	35	0	0	+14.49	+ 5.00
	LOW	HC/CO	70	- 3.69	- 2.25	+ 9.52	+ 5.00
	LOW	HC/CO	100	+ 1.65	+ 1.50	0	0
HIGH ALTITUDE	HIGH	HC/CO	35	+ 0.29	+ 0.10	- 3.23	- 1.20
	HIGH	HC/CO	70	- 3.39	- 2.40	+ 1.54	+ 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	+ 4.35	+ 4.00
	LOW	HC/CO	35	+ 0.95	+ 0.25	+10.15	+ 3.5
	LOW	HC/CO	70	- 1.64	- 1.00	- 0.95	- 0.50
	LOW	HC/CO	100	- 0.28	- 0.25	+ 2.86	+ 2.50
RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1716	10.5	5.25	5.55	18.5
	HIGH	CO	8.1	9.65	6.3	5.7	17.8
HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	0	62	5	26
6750 Feet Altitude	LOW	0	5	11	120	20	58

Table 7-1. DATA COMPOSITE - LABORATORY TEST (Cont'd)

HORIBA MEXA 300A

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0	0
	115V	HIGH	CO	0	0

Table 7-2. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **HORIBA MEXA 300A**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	**HC**	9	25	9	15
	LOW	**CO**	8	18	9	12

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	**LOW**	**HC**	2.5	5.0	1.75	2.0
	LOW	**CO**	3.5	1.6	3.5	1.0

GAS INTERFERENCE (% of FS) **CYCLE 1**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	2.5	0	0	0
	LOW	**CO**	1.0	1.5	-	0	1.0	0.5

GAS INTERFERENCE (% of FS) **CYCLE 2**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	0	0	0	0
	LOW	**CO**	0	0	-	0.4	0	0

GAS INTERFERENCE (% of FS) **CYCLE 3**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	1.0	-	1.25	1.25	1.25	0
	LOW	**CO**	0.5	0	0	0	0	0

GAS INTERFERENCE (% of FS) **CYCLE 4**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	1.25	1.25	0	0
	LOW	**CO**	1.0	0	0	0	0	0.5

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	**HIGH**	**HC**	1716	21	11.5	6.5	5.5
	HIGH	**CO**	8.1	17.5	11.5	5.5	5.0

HORIBA MEXA 300A

Table 7-2. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+0.29	+0.10	-3.23	-1.20
	HIGH	HC/CO	70	-4.72	-3.35	+1.54	+1.00
	HIGH	HC/CO	100	-1.62	-1.45	0	0
	LOW	HC/CO	35	-2.86	+0.75	+10.14	+3.5
	LOW	HC/CO	70	-1.64	+1.00	-0.95	-0.5
	LOW	HC/CO	100	0	0	+2.86	+2.5
CYCLE 2	HIGH	HC/CO	35	+1.74	+0.6	-1.88	-0.7
	HIGH	HC/CO	70	-3.03	-2.15	0	0
	HIGH	HC/CO	100	+0.61	+0.55	0	0
	LOW	HC/CO	35	-0.95	-0.2	+13.04	+3.6
	LOW	HC/CO	70	-2.05	-1.0	0.0	0
	LOW	HC/CO	100	+0.82	+0.6	+1.14	+0.8
CYCLE 3	HIGH	HC/CO	35	+1.74	+0.60	-1.88	-0.70
	HIGH	HC/CO	70	-1.97	-1.4	-0.77	-0.50
	HIGH	HC/CO	100	+1.17	+1.05	-2.72	-2.5
	LOW	HC/CO	35	-1.90	-0.50	+10.14	+3.5
	LOW	HC/CO	70	-2.05	-1.25	+4.76	+2.5
	LOW	HC/CO	100	+1.10	+1.00	+3.43	+3.00
CYCLE 4	HIGH	HC/CO	35	+1.87	+0.65	-1.08	-0.40
	HIGH	HC/CO	70	-1.55	-1.1	+1.54	+1.00
	HIGH	HC/CO	100	+1.17	+1.05	+2.07	+1.90
	LOW	HC/CO	35	-12.38	-3.25	+14.49	+5.0
	LOW	HC/CO	70	-4.1	-2.50	0	0
	LOW	HC/CO	100	+1.37	+1.25	+2.86	+2.50

Table 7-3. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

HORIBA MEXA 300 A

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	400/2	HC/CO	50	- 34.31	- 7.58	+ 11.11	+ 2.5
	400/2	HC/CO	30	- 40.86	- 11.23	+ 15.38	+ 1.0
	400/2	HC/CO	IDLE	- 49.49	- 31.85	+ 7.14	+ 2.0
CYCLE 2	400/2	HC/CO	50	- 12.28	- 2.8	- 6.78	- 2.0
	400/2	HC/CO	30	- 21.59	- 5.85	- 14.49	- 1.0
	400/2	HC/CO	IDLE	- 32.12	- 18.93	- 10.62	+ 6.0
CYCLE 3	400/2	HC/CO	50	- 2.41	- 0.55	- 13.79	- 4.0
	400/2	HC/CO	30	- 7.11	- 1.88	0	0
	400/2	HC/CO	IDLE	- 19.43	- 10.25	- 10.71	- 4.5
CYCLE 4	400/2	HC/CO	50	+ 5.91	+ 1.33	+ 57.14	+ 10.0
	400/2	HC/CO	30	+ 0.2	+ 0.05	+1100.0	+ 5.5
	400/2	HC/CO	IDLE	- 16.38	- 8.33	+ 18.64	+ 11.0
LEAN MODE CYCLE 1	400/2	HC/CO	50	- 4.88	- 1.03	+ 7.14	+ 2.0
	400/2	HC/CO	30	- 9.75	- 2.03	+ 25.0	+ 1.5
	2000/2	HC/CO	IDLE	- 11.89	+ 3.72	- 47.37	- 4.5
CYCLE 2	400/2	HC/CO	50	- 10.53	- 2.85	- 15.09	- 4.0
	400/2	HC/CO	30	- 13.54	- 3.53	0	0
	2000/2	HC/CO	IDLE	+ 16.67	+ 5.0	0	0
CYCLE 3	400/2	HC/CO	50	- 5.21	- 1.38	- 10.71	- 3.0
	400/2	HC/CO	30	+ 14.87	+ 3.08	+ 33.33	+ 1.5
	2000/2	HC/CO	IDLE	- 24.56	- 5.86	0	0
CYCLE 4	400/2	HC/CO	50	+ 20.92	+ 4.33	+ 13.64	+ 3.0
	400/2	HC/CO	30	+ 8.72	+ 1.93	+400.0	+ 4.0
	400/2	HC/CO	IDLE	- 27.26	- 24.83	+ 66.67	+ 7.0

Table 7-3. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

HORIBA MEXA 300 A

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	400/2	HC/CO	50	+ 56.4	+ 14.88	- 7.69	- 2.5
	400/2	HC/CO	30	- 38.1	- 12.0	- 25.0	- 2.5
	400/10	HC/CO	IDLE	- 11.43	- 9.68	+ 1.55	+ 0.7
CYCLE 2	400/2	HC/CO	50	+ 16.96	+ 4.35	- 10.71	- 3.0
	400/2	HC/CO	30	+ 10.82	+ 3.05	- 14.29	- 1.0
	400/10	HC/CO	IDLE	- 7.77	- 5.9	+ 3.02	+ 1.2
CYCLE 3	400/2	HC/CO	50	- 28.79	- 7.08	- 9.09	- 2.5
	400/2	HC/CO	30	- 28.79	- 7.08	0	0
	400.10	HC/CO	IDLE	+ 5.62	+ 3.73	+ 9.47	+ 3.2
CYCLE 4	400/2	HC/CO	50	- 20.72	- 4.58	- 37.5	- 12.0
	400/2	HC/CO	30	- 24.17	- 6.38	- 23.08	- 1.5
	400/10	HC/CO	IDLE	- 19.85	- 13.0	- 16.67	- 6.0

Table 7-4. DIAGNOSTIC TEST

HORIBA MEXA 300 A

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	400	HC	875	1142	- 23.38	- 13.35
	10%	CO	1.90	2.08	- 8.65	- 1.8
NORMAL IDLE	400	HC	340	374	- 9.09	- 8.5
	10%	CO	1.8	2.01	- 10.45	- 2.1
IGNITION ADVANCE	400	HC	325	374	- 13.1	- 12.25
	10%	CO	2.10	2.18	- 3.67	- 0.8
IGNITION RETARD	400	HC	325	358	- 9.22	- 8.25
	10%	CO	2.4	2.45	- 2.04	- 0.5

Table 7-5. DURABILITY TEST DATA

INSTRUMENT: HORIBA MEXA 300 A

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	272
HC EXPOSURE (PPM-HRS.)	275,040
CO EXPOSURE (%-HRS.)	443
NO EXPOSURE (PPM-HRS.)	28,016
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	2
SHOCK TEST FAILURE RATE (Failure/Day %)	11.76
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	2
HC SPAN	0
CO ZERO	0
CO SPAN	0
AVERAGE DAILY SPAN DRIFT	
HC%	5.75
CO%	4.54
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	54.00
PER 100 HRS.	19.80
B DRAIN HOSE	
TOTAL	71.0
PER 100 HRS.	26.1
C REZERO	
TOTAL	3.0
PER 100 HRS.	1.1
D. SAMPLING SYSTEM	
TOTAL	2.00
PER 100 HRS.	0.74
E. OTHER	
TOTAL	--
PER 100 HRS.	--

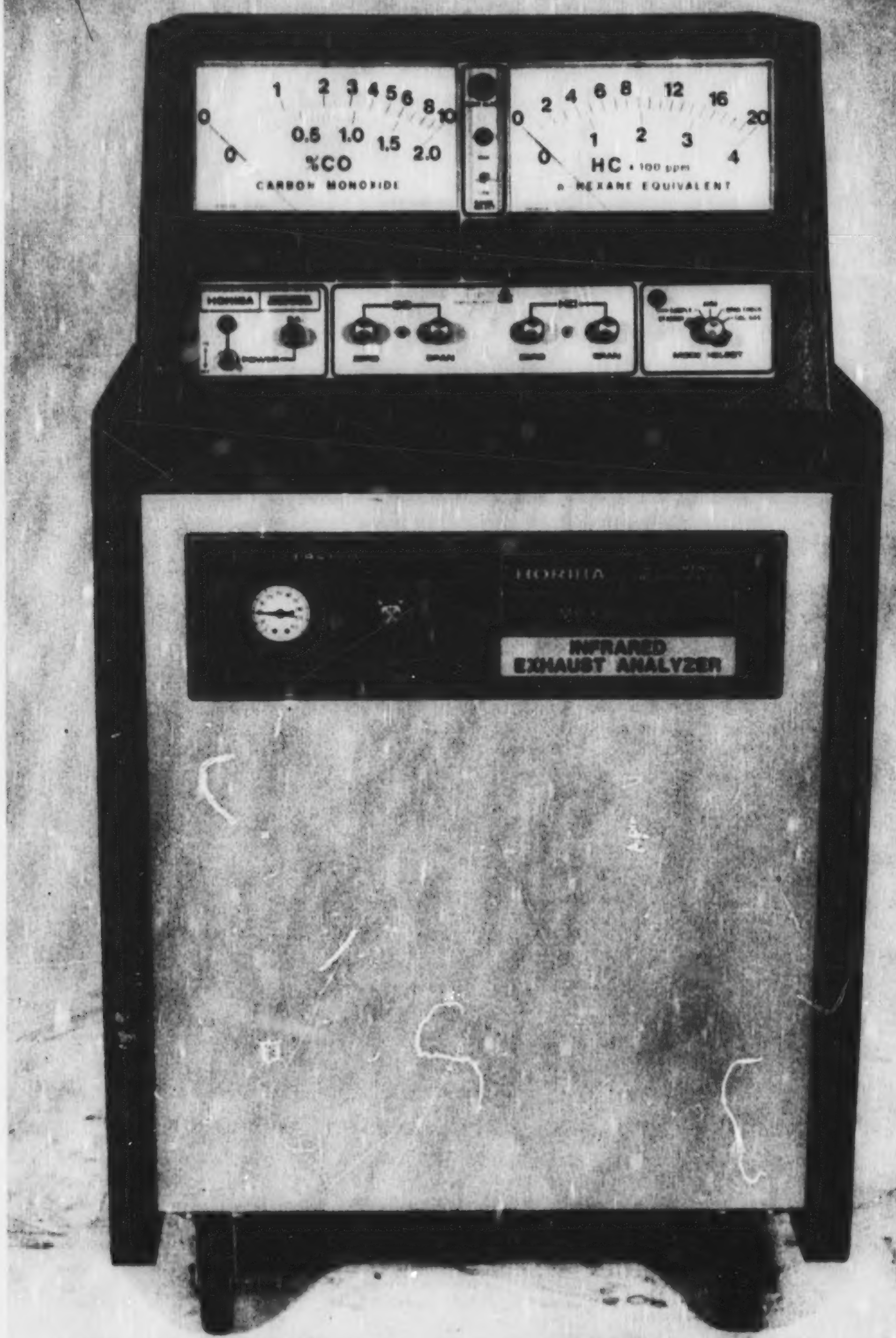
0
1
2
3
4
5
6
8
10
0
0.5
1.0
1.5
2.0
%CO
CARBON MONOXIDE
0
2
4
6
8
12
16
20
0
1
2
3
4
HC × 100 ppm
n HEXANE EQUIVALENT
HORIBA
ZERO
SPAN
ZERO
SPAN
MODE SELECT
HORIBA
INFRARED
EXHAUST ANALYZER

Figure 7-1. HORIBA MEXA 300A INFRARED EXHAUST ANALYZER

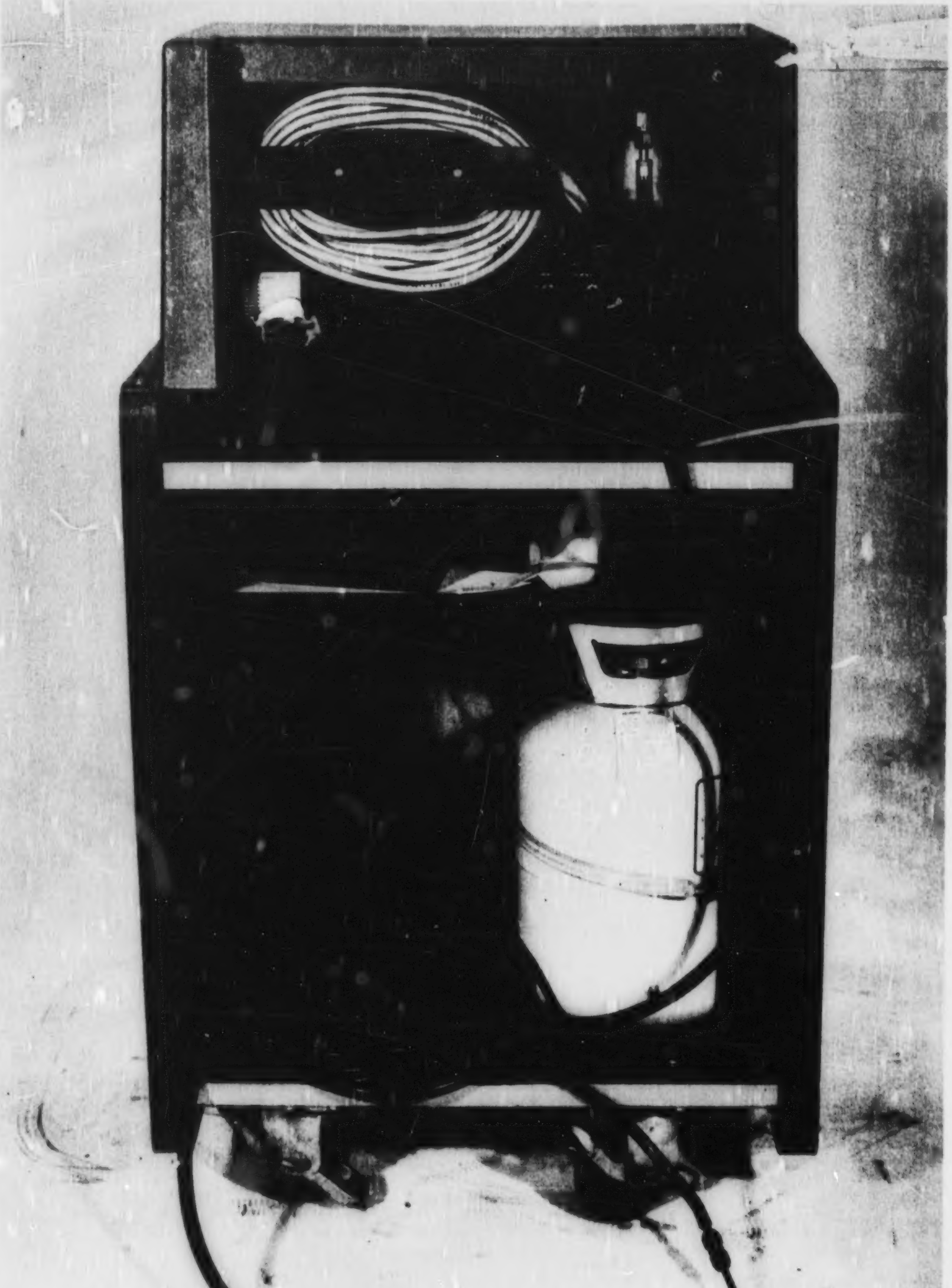

Figure 7-2. HORIBA MEXA 300A INFRARED EXHAUST ANALYZER (BACK)

Figure 7-3. HORIBA MEXA 300A INFRARED EXHAUST ANALYZER (LEFT SIDE)

7.2 BARNES 8335C EMISSION ANALYZER

Manufacturer - Barnes Engineering Company.

Description - HC/CO exhaust analyzer configured as a bench top analyzer physically connected to a cart. The unit could be used without the cart if desired. The cart incorporates one low shelf for storage.

Dimensions -

Analyzer:
Height - 12 inches
Width - 20 inches
Depth - 16 inches
Weight - 45 lbs.

Analyzer on Cart:
Height - 46 inches
Width - 22 inches
Depth - 23 inches

The cart shelf is 22 inches wide and 20 inches deep, with a 1-inch lip. The shelf is 5 inches from the floor.

Material of Construction - Main analyzer cabinet and cart are sheet metal. Cabinet and cart are welded and screwed together.

Color - Analyzer - Black case with yellow front. Cart - Yellow shelves with black legs.

Mobility - Two, 4-inch diameter nonsteerable wheels in rear, solid legs in front. This unit has the handle on the front and wheels at the rear.

Accessories - Tail pipe probe, 20-foot hose, rollaway cart, particulate filter (0.6 micron), operator's manual.

Control Package -

Front access - Mode select switch (four positions)
1. Off
2. Standby
3. Calibrate
4. Run

HC zero knob
HC HI/LO toggle switch
CO zero knob
CO zero knob
CO HI/LO toggle switch
Test button (electronic calibration)
Filter light (red) indicates restriction
ON light
CO_2 light (indicates presents of CO_2 in exhaust stream)

Side Access - (Recess in right side of cabinet)
HC span knob

HC test adjust screw (used for gas calibration)
CO span knob
CO test adjust screw

Rear Panel Access
2.5 amp fuse cartridge
HC and CO recorder outputs

Meters - 8", 90° swing

High scale - red figures
Low scale - flue figures
Graduations - Black
Meter visibility and readability is rated as good.

Ranges - HC - 2000 ppm in 50 ppm increments
400 ppm in 10 ppm increments
CO - 10% in 0.2% increments
2% in 0.05% increments

These meters were very sensitive to static electricity caused by brushing against the clear meter lens. The application of an antistatic coating on the meter lens is definitely needed.

Altitude Compensation - Manual set with HC and CO test adjustment screws. 0- to 7,000-foot scales on HC and CO meter faces.

Probe - Convoluted flexible tube with sealed tip and perpendicular sample holes. Tail pipe clamp used to keep probe in exhaust pipe.

Filter and Sample Handling - External particulate (0.6 micron) filter in water separator. Dual-head pump moves sample through one head with the other head removing water from separator through a particulate filter to the drain hose. Water particulate filter protects the pump head.

Cal Gas Inlet - Rear of analyzer.

Power Requirements - 115 VAC/60HZ 300 watts

Operating Principles - Multi-channel infrared interference photometer with solid state electronics. Mechanical filter wheel with HC/CO reference/CO_2 optical filter windows. Solid state detector, hot wire source.

Calibration - Electronic signal by test button on front panel. Altitude of site set on front meter faces. Original factory gas calibration at zero elevation. On-site gas calibration through rear port with mode switch in calibrate.

Operation and Calibration - Straightforward. Operation and calibration data on analyzer side panel and in manual.

1. Set to standby
2. Warm up

3. Set in calibrate
4. Adjust zero
5. Set altitude of test site (test button depressed)
6. Ready for use

Gas calibration can be performed with mode switch in standby and span knob adjustment. Calibration instructions on instrument side panel.

7.2.1 Operational Performance Comments

The most obvious problem encountered while using this instrument was the very awkward mobility that this specific cabinet and cart design produced. The unit has an extremely high C.G. and with the present handle location and rear wheel position, it is difficult to move around.

Operationally, this unit was easy to use and calibrate.

The meters were front-lighted and this enhanced meter visibility.

The HC and CO meters could be set to high or low ranges individually with their own range toggle switch. This was a nice feature except that there were no range identification lights so the toggle switch's position was the only visual range indication. This lead to a slight degree of confusion during vehicle testing.

The electronic test button (calibration button) worked well and gave a quick indication of calibration.

This unit is equipped to detect CO_2 and displays CO_2 presence with a front panel light. The intended use of this feature is to identify valid tail pipe exhaust readings by indicating high CO_2 levels. Low CO_2 levels would indicate exhaust dilution and, thus, invalid tail pipe exhaust readings. This feature worked very well during the vehicle tests. The CO meter on this unit was the only one that was linear. The unit incorporates an eight-point linearized circuit to achieve this linear output. When used in conjunction with an auxiliary recorder, this would be a very useful feature. For the tests run in this program this feature had negligible effect.

Gas calibration using the rear panel calibration gas port was simple. Altitude correction with the scales on the front meter faces was also easy.

In the laboratory tests, this instrument showed reasonable warm up times. Zero drift was good at medium and low temperatures. During the high temperature test, the unit failed to operate properly. The CO meter could not be zeroed. The lowest obtainable reading at the end of the zero pot was 0.5 percent. The HC channel appeared to function normally. Upon returning the instrument to 70°F, the CO channel resumed normal operation. Additionally, later in the diagnostic tests, the instrument stopped responding to sample gas altogether. This failure was identified and attributed to a solenoid valve stuck in the calibration position. Due to the multiple failures in the temperature test sequences, the Barnes was found to be the eighth most accurate instrument overall. Exclusive of the test failures, the actual demonstrated accuracy of the instruments was generally well within ±3 percent full scale except for the

35 percent full scale CO tests. The low CO scale consistently showed positive errors of 4 to 5 percent full scale. Operation at high altitude showed no significant degradation in accuracy.

The Barnes unit showed reasonable and fairly consistent response times.

This unit was not sensitive to acetylene or benzene. It was most sensitive to isobutylene, followed by toluene, methane and ethylene. Input voltage variation caused essentially no signal level change.

In general, the Barnes showed effects of interference gases to be on the order of approximately 1 percent or less. This is an acceptable level. No significant interference problem was noted.

The unit showed slightly below average correlation with the EPA bench during the vehicle exhaust tests. The low range CO and low range HC values showed larger errors, especially during idle mode.

In the durability tests, the Barnes ran only 16 hours. This corresponds to a HC exposure of 16,160 ppm-hours and CO exposure of 33 percent-hours.

This early failure was indicated by radical and uncontrollable up-scale meter deflections (both scales). Unfortunately, failure occurred too early in the durability test to draw reasonable conclusions with regard to maintenance requirements. During the time it did run though, the instrument appeared to have a slight moisture handling problem complicated by the fact that the various filters on this unit are relatively difficult to service and filter changing is time-consuming. In the short time period of operation, the probe and sample hose showed no degradation.

Test data for Barnes 8335C Emission Analyzer are shown in Tables 7-6 through 7-10.

Photographs of the instrument are shown in Figures 7-4 through 7-7.

Table 7-6. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: BARNES 8335 C

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	7	13	26	13
	LOW	CO	7	13	26	12

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	1.25	INSTRUMENT	1.25	0.5
	LOW	CO	0	MALFUNCTION	2.5	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	1.0	-	1.25	0	0	0
	LOW	CO	0	0.5	-	0	0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	0	0	- 1.88	- 0.7
	HIGH	HC/CO	70	- 2.84	- 2.05	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 1.21	- 1.1	+ 1.09	+ 1.0
	LOW	HC/CO	35	+ 1.87	+ 0.5	+ 7.25	+ 2.5
	LOW	HC/CO	70	+ .80	+ 0.5	+ 1.90	+ 1.0
	LOW	HC/CO	100	+ 1.80	+ 1.0	- 0.57	- 0.5
CYCLE 2	HIGH	HC/CO	35	INSTRUMENT	MALFUNCTION		
	HIGH	HC/CO	70				
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				

Table 7-6. DATA COMPOSITE - LABORATORY TEST (Cont'd)

BARNES 8335C

CYCLE 3	HIGH	HC/CO	35	0	0	- .54	- 0.2
	HIGH	HC/CO	70	- 1.80	- 1.3	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.16	- 0.15	- 1.09	- 1.0
	LOW	HC/CO	35	0	0	+15.94	+ 4.4
	LOW	HC/CO	70	+ .40	+ 2.5	+ .95	+ 0.5
	LOW	HC/CO	100	+ 1.08	+ 1.0	+ .57	+ 0.5
CYCLE 4	HIGH	HC/CO	35	+ 2.0	+ 0.7	+ 1.88	+ 0.7
	HIGH	HC/CO	70	- 0.41	- 0.3	+ 4.62	+ 3.0
	HIGH	HC/CO	100	+ 0.93	+ .85	+ 0.11	+ 1.0
	LOW	HC/CO	35	+ 2.80	+ .75	+14.49	+ 5.0
	LOW	HC/CO	70	+ 0.40	+ .25	+ 0.95	+ 0.5
	LOW	HC/CO	100	+ 0.32	+ .25	- 0.57	- 0.5
HIGH ALTITUDE	HIGH	HC/CO	35	0	0	- .54	- 0.2
	HIGH	HC/CO	70	- 3.18	- 2.3	+ 1.85	+ 1.2
	HIGH	HC/CO	100	- 0.71	- 0.65	- 0.22	- 0.2
	LOW	HC/CO	35	0	0	+14.49	+ 5.0
	LOW	HC/CO	70	- 0.4	- 0.25	+ 0.95	+ 0.5
	LOW	HC/CO	100	+ 2.16	+ 2.0	- 0.57	- 0.5

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1716	11.95	INSTRUMENT	17.5	16.3
	HIGH	CO	8.1	11.8	FAILED No DATA	22.5	15.9

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	5	84	11	31
6750 Feet Altitude	LOW	0	0	8	85	16	39

Table 7-6. DATA COMPOSITE - LABORATORY TEST (Cont'd)

BARNES 8335C

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10% + 10%	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10% - 10%
	115V	HIGH	HC	0	0
	115V	HIGH	CO	0.5	0

Table 7-7. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: BARNES 8335C

	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
WARMUP TIME (Min.)	LOW	HC	9	20	11	15
		CO	10	20	15	15

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	1.25	1.75	3.5	0.5
		CO	1.5	1.0	2.5	0.5

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 1	LOW	HC	2.5	----	0.5	0.5	0	0
		CO	1.5	1.0	---	1.0	0.5	0
GAS INTERFERENCE (% of FS) CYCLE 2	LOW	HC	0.75	--	2.5	0	0	0
		CO	0	0	---	0	0	0
GAS INTERFERENCE (% of FS) CYCLE 3	LOW	HC	0.5	--	1.0	0	0	0
		CO	0	0	---	0	0	0
GAS INTERFERENCE (% of FS) CYCLE 4	LOW	HC	0.5	--	1.5	0	0	0
		CO	0	0	---	0	0	1.0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1749	19.5	19.5	8	7.5
		CO	8.1	19.5	19.5	7	6.5

Table 7-7. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

BARNES 8335C

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 2.00	+ 0.70	+ 2.15	+ 0.80
	HIGH	HC/CO	70	- 3.87	- 2.80	+ 3.85	+ 2.50
	HIGH	HC/CO	100	- 1.26	- 1.15	- 1.08	- 1.00
	LOW	HC/CO	35	+ 8.41	+ 2.25	+18.84	+ 6.50
	LOW	HC/CO	70	+ 1.21	+ 0.75	+ 6.67	+ 3.50
	LOW	HC/CO	100	+ 2.16	+ 2.0	+ 2.29	+ 2.00
CYCLE 2	HIGH	HC/CO	35	+ 5.56	+ 1.95	+ 1.61	+ 0.6
	HIGH	HC/CO	70	- 2.49	- 1.8	+ 2.31	+ 1.5
	HIGH	HC/CO	100	- 0.17	- 0.15	- 2.17	- 2.0
	LOW	HC/CO	35	+ 6.54	+ 1.75	+ 7.25	+ 2.5
	LOW	HC/CO	70	+ 0.40	+ 0.25	+ 2.85	+ 1.5
	LOW	HC/CO	100	0	0	- 1.71	- 1.5
CYCLE 3	HIGH	HC/CO	35	+ 4.14	+ 1.45	- 0.54	- 0.20
	HIGH	HC/CO	70	- 1.80	- 1.30	+ 3.08	+ 2.00
	HIGH	HC/CO	100	- 0.16	- 0.15	- 0.54	- 0.50
	LOW	HC/CO	35	0	0	+ 4.35	+ 1.50
	LOW	HC/CO	70	- 2.81	- 1.75	- 8.57	- 4.50
	LOW	HC/CO	100	+ 1.08	+ 1.00	- 0.57	- 0.50
CYCLE 4	HIGH	HC/CO	35	+ 2.43	+ 0.85	- 2.15	- 0.80
	HIGH	HC/CO	70	- 1.94	- 1.40	+ 1.85	+ 1.20
	HIGH	HC/CO	100	0	0	- 0.98	- 0.90
	LOW	HC/CO	35	+ 5.61	+ 1.50	+15.94	+ 5.50
	LOW	HC/CO	70	0	0	+ 1.90	+ 1.0
	LOW	HC/CO	100	+ 1.08	+ 1.00	- 1.71	- 1.50

Table 7-8. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

BARNES 8335C

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	400/2	HC/CO	50	+ 0.2	+ 0.05	- 7.69	- 2.5
	400/2	HC/CO	30	+ 2.4	+ 0.65	+ 33.33	+ 2.0
	2000/2	HC/CO	IDLE	+ 23.1	+ 4.03	+ 38.89	+ 7.0
CYCLE 2	400/2	HC/CO	50	+ 14.89	+ 3.5	- 2.3	- 1.0
	400/2	HC/CO	30	+ 3.32	+ 0.9	+ 71.43	+ 5.0
	400/2	HC/CO	IDLE	+ 12.86	+ 7.98	+ 35.42	+ 17.0
CYCLE 3	400/2	HC/CO	50	+ 26.1	+ 5.95	+ 17.65	+ 6.0
	400/2	HC/CO	30	+ 12.21	+ 3.4	+109.09	+ 6.0
	400/2	HC/CO	IDLE	+ 8.78	+ 5.65	+ 36.23	+ 12.5
CYCLE 4	400/2	HC/CO	50	+ 7.71	+ 1.95	+ 57.41	+ 15.5
	400/2	HC/CO	30	+ 14.69	+ 3.86	+130.0	+ 6.5
	400/2	HC/CO	IDLE	- 12.06	- 7.2	+ 52.63	+ 25.0
LEAN MODE CYCLE 1	400/2	HC/CO	50	+ 30.8	+ 6.48	- 2.78	- 1.0
	400/2	HC/CO	30	+ 24.19	+ 5.6	+ 15.38	+ 1.0
	2000/2	HC/CO	IDLE	+ 56.96	+ 18.16	+ 43.75	+ 3.5
CYCLE 2	400/2	HC/CO	50	+ 3.75	+ 0.98	+ 14.04	+ 4.0
	400/2	HC/CO	30	+ 6.16	+ 1.62	+100.0	+ 6.0
	2000/2	HC/CO	IDLE	+ 36.13	+ 11.28	+ 78.95	+ 7.5
CYCLE 3	400/2	HC/CO	50	+ 13.35	+ 3.48	+ 29.03	+ 9.0
	400/2	HC/CO	30	+ 39.06	+ 8.06	+120.0	+ 6.0
	2000/2	HC/CO	IDLE	- 1.07		- 0.33	+112.5
CYCLE 4	400/2	HC/CO	50	+ 26.04	+ 5.48	+ 32.08	+ 8.5
	400/2	HC/CO	30	+ 27.73	+ 6.03	+100.0	+ 5.0
	2000/2	HC/CO	IDLE	+ 64.62	+ 10.8	+257.14	+ 18.0

Table 7-8. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

BARNES 8335 C

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	400/2	HC/CO	50	+ 56.4	+ 14.88	- 7.69	- 2.5
	400/2	HC/CO	30	- 38.1	- 12.0	- 25.0	- 2.5
	400/10	HC/CO	IDLE	- 11.43	- 9.68	+ 1.55	+ 0.7
CYCLE 2	400/2	HC/CO	50	+ 10.47	+ 2.73	+ 29.03	+ 9.0
	400/2	HC/CO	30	+ 15.25	+ 4.3	+ 78.57	+ 5.5
	400/10	HC/CO	IDLE	+ 16.73	+ 12.83	+ 21.69	+ 8.2
CYCLE 3	400/2	HC/CO	50	+ 23.56	+ 5.63	+ 7.14	+ 2.5
	400/2	HC/CO	30	+ 32.25	+ 7.93	+ 91.67	+ 5.5
	400/10	HC/CO	IDLE	+ 34.7	+ 21.13	+ 30.84	+ 9.9
CYCLE 4	400/2	HC/CO	50	+ 20.04	+ 4.93	+ 26.47	+ 9.0
	400/2	HC/CO	30	+ 27.96	+ 7.38	+ 91.67	+ 5.5
	400/10	HC/CO	IDLE	+ 34.03	+ 21.9	+ 26.07	+ 9.1

Table 7-9. DIAGNOSTIC TEST

BARNES 8335 C

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED			INOPERATIVE			
NORMAL IDLE			INOPERATIVE			
IGNITION ADVANCE			INOPERATIVE			
IGNITION RETARD			INOPERATIVE			

Table 7-10. DURABILITY TEST DATA

INSTRUMENT: BARNES 8335C

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	16
HC EXPOSURE (PPM-HRS.)	16,160
CO EXPOSURE (%-HRS.)	33
NO EXPOSURE (PPM-HRS.)	1,664
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	NO TEST DATA
SHOCK TEST FAILURE RATE (Failure/Day %)	NO TEST DATA
INCIDENCE OF FAILURE IN EACH MODE	NO TEST DATA
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	NO TEST DATA
HC%	
CO%	
NO%	
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	--
PER 100 HRS.	--
B DRAIN HOSE	
TOTAL	1
PER 100 HRS.	6.25
C REZERO	
TOTAL	--
PER 100 HRS.	--
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	--
PER 100 HRS.	--

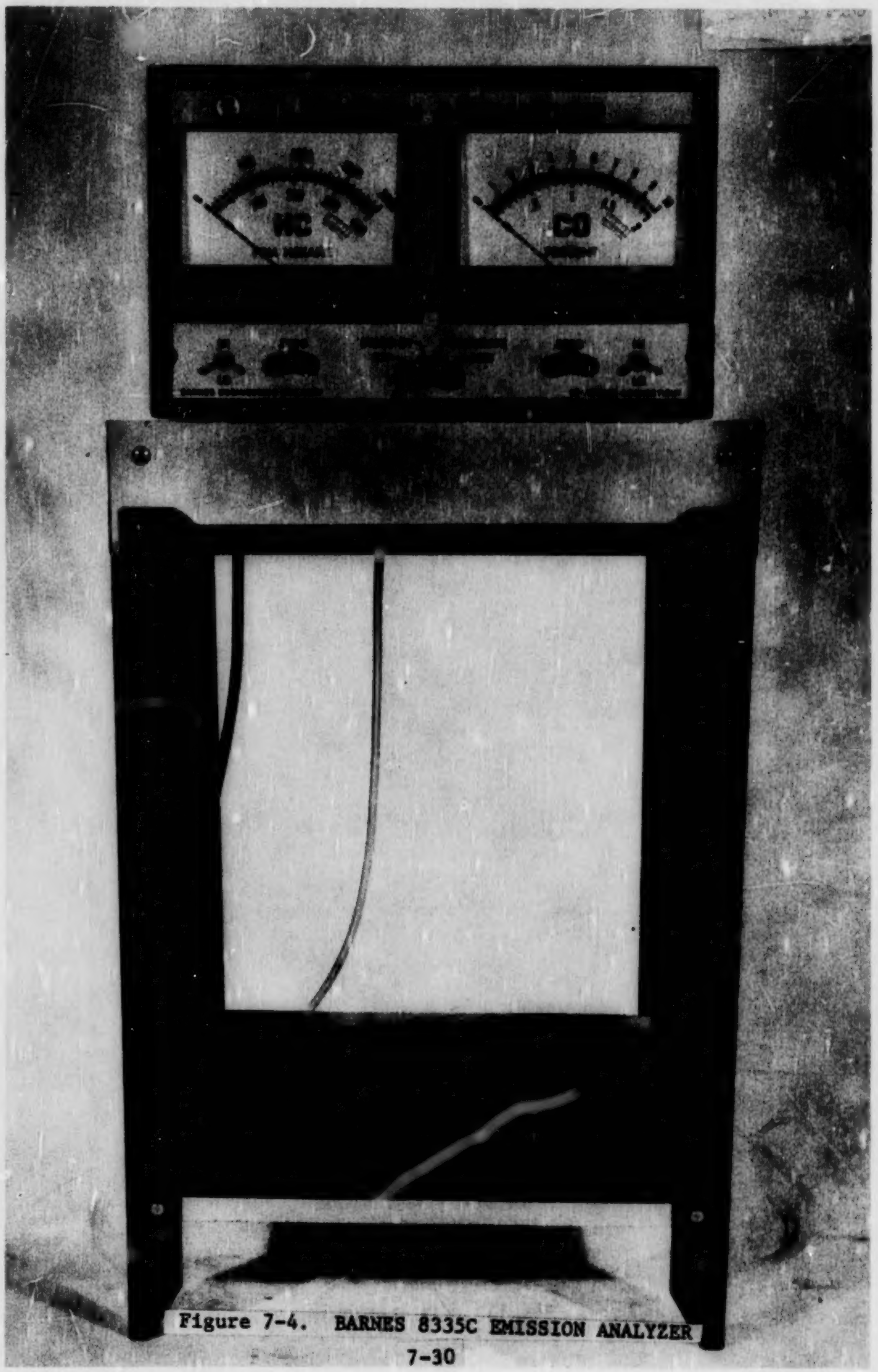

Figure 7-4. BARNES 8335C EMISSION ANALYZER

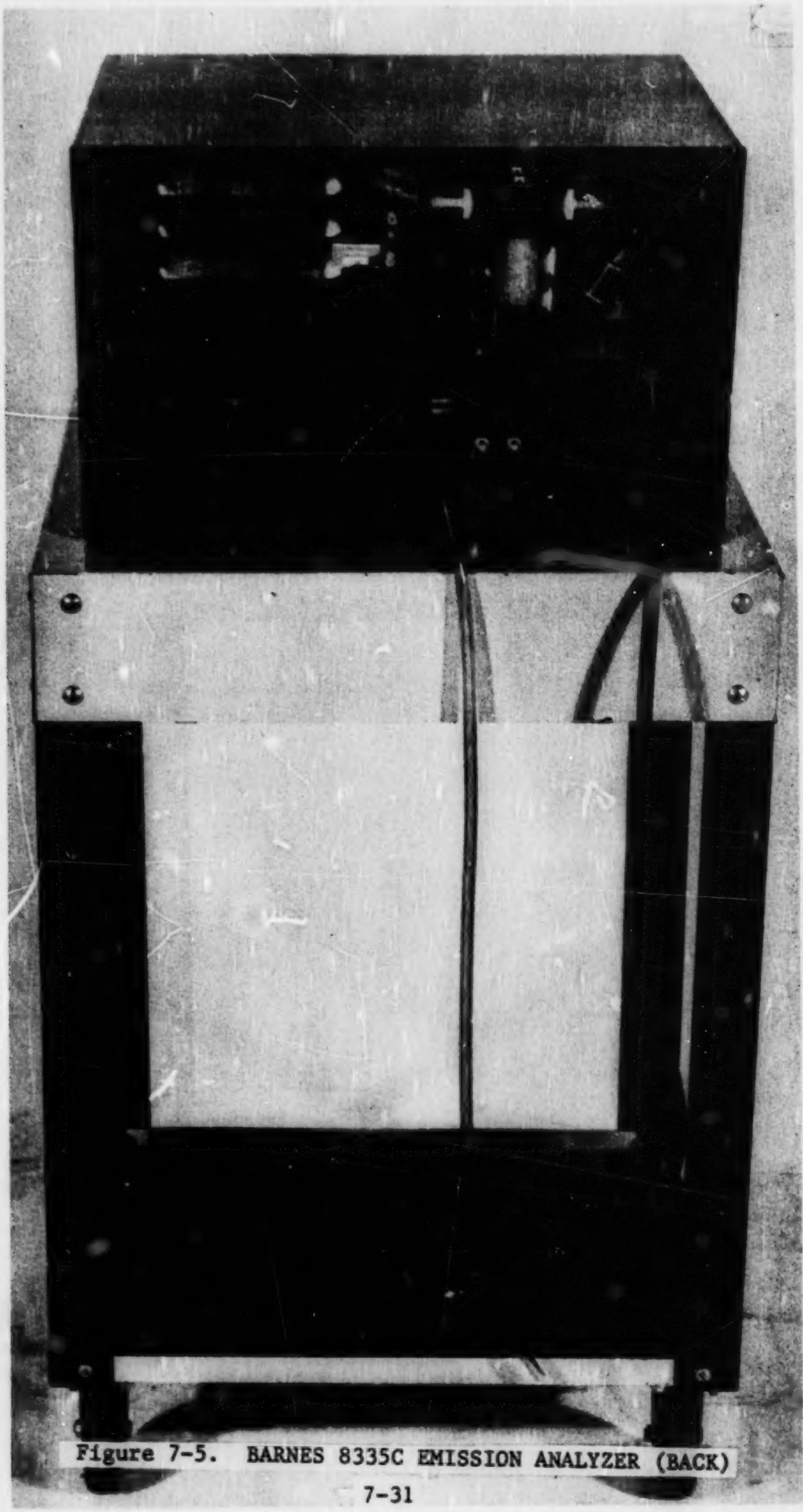

Figure 7-5. BARNES 8335C EMISSION ANALYZER (BACK)

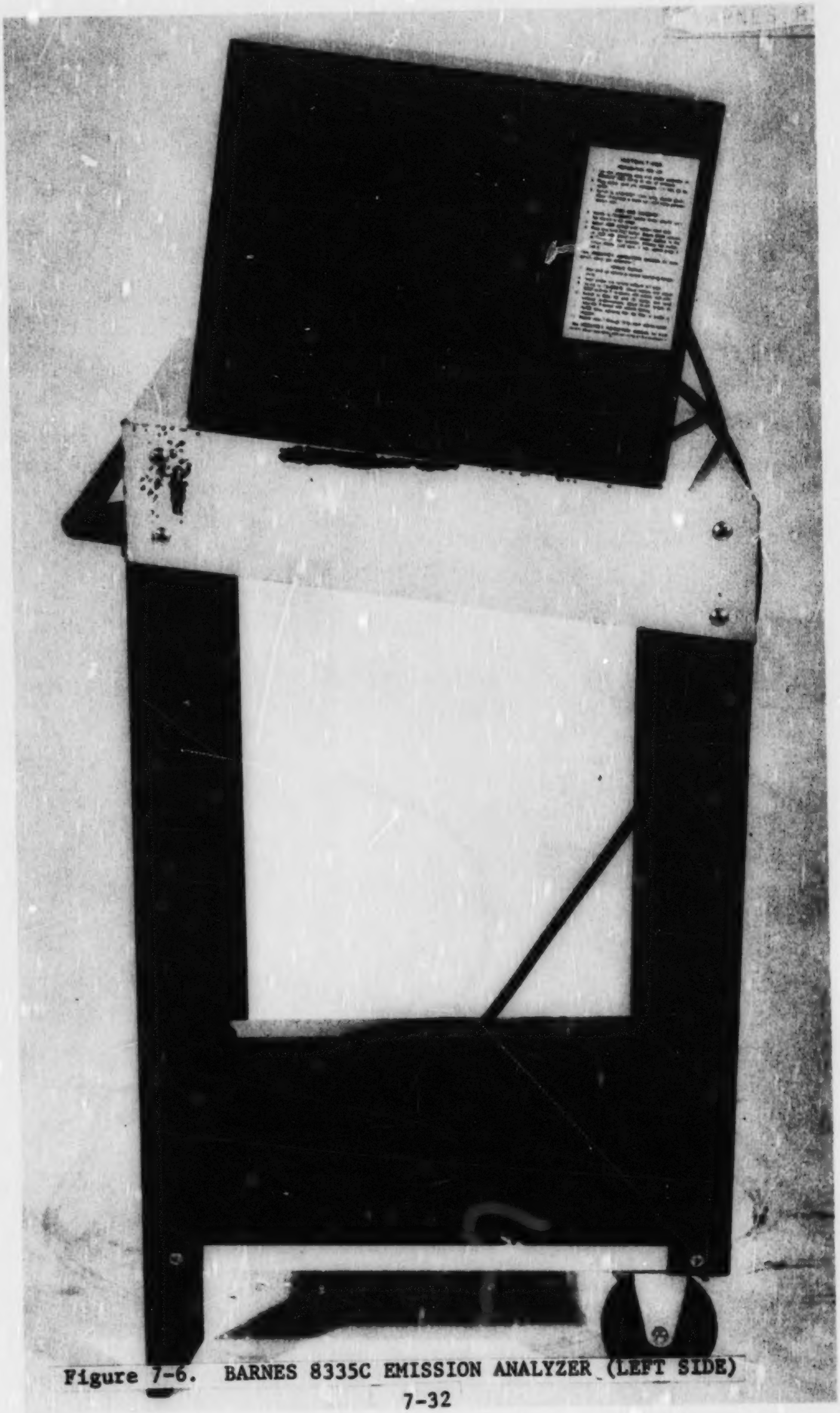

Figure 7-6. BARNES 8335C EMISSION ANALYZER (LEFT SIDE)

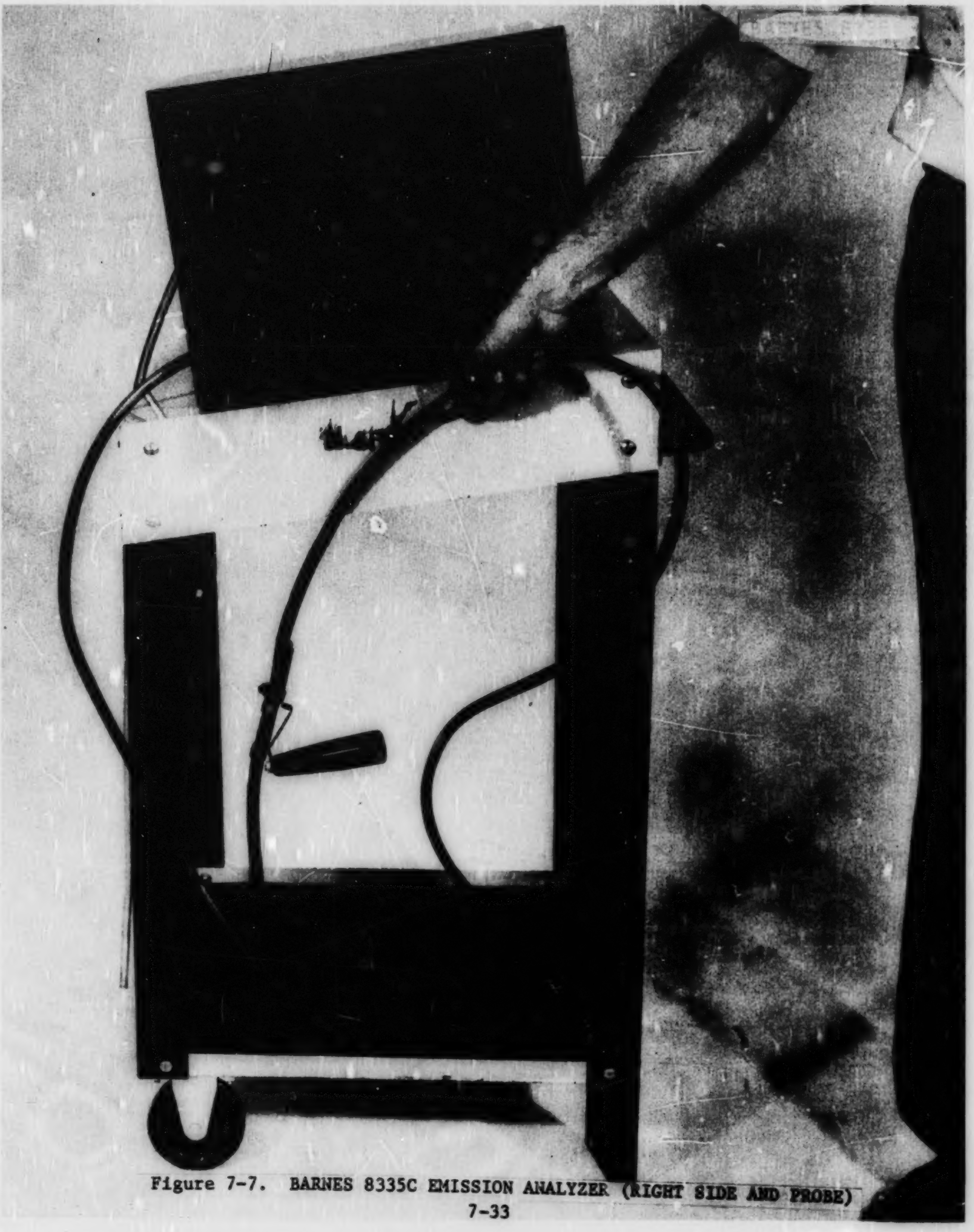

Figure 7-7. BARNES 8335C EMISSION ANALYZER (RIGHT SIDE AND PROBE)

7.3 SCOTT IIIC EXHAUST EMISSION ANALYZER

Manufacturer - Chrysler Corporation

Description - HC/CO analyzer configured as a bench to unit but available with a two-wheel cart. The analyzer can be used with or without the cart with equal ease. The cart incorporates storage areas.

Dimensions -

Analyzer:	Height - 9 inches
	Width - 13 inches
	Depth - 10 inches
	Weight - 20 lbs.
Cart:	Height - 38 inches
	Width - 15 inches
	Depth - 15 inches
	Weight - 30 lbs.

The cart incorporates a top drawer and a lower storage area with a snap-closing door.

Material of Construction - Main analyzer cabinet is aluminum sheet. Cart is sheet metal. Method of joining - welding and screws.

Color - Analyzer - Blue with silver front. Cart - red.

Mobility - Two, rear-mounted, 7-inch wheels. Round tube cart handle is at top rear of instrument. Mobility and stability of this combination is very good. Low C.G. gives very stable feel.

Accessories - Tail pipe probe with 25-foot sample hose (two pieces), water trap, operator's manual.

Control Package -

Front access -
HC - course zero adjust (screw)
HC - fine zero adjust (knob)
HC - span adjust (screw)
HC - cal adjust (screw)
HC - range switch (two-position toggle)
CO - course zero adjust (screw)
CO - fine zero adjust (knob)
CO - span adjust (screw)
CO - cal adjust (screw)
CO - range switch (two-position toggle)
POWER - push button incorporating indicating lame
Calibrate Check - push button
Low Flow - light
No external fuses or breakers (external housing must be removed to replace lamp fuse)

Rear Access -
Recorder jack

Meters - 6-inch, 90° swing

High scale - green graduations - black figures
Low scale - red graduations - black figures
White background.

Ranges - HC - 2000 ppm in 50 ppm increments
300 ppm in 50 ppm increments
CO - 10% in 0.2% increments
0.5% in 0.01% increments

Meter visibility and readability rated as good. The HC meter on this instrument was sensitive to static electricity (soft cloth rubbed against lens).

Altitude Compensation - On chart contained in operator's manual. Requires use of correction factor. Correction not needed if gas calibration used at altitude in question.

Probe - Three-foot, convoluted tube with sealed end and perpendicular gas entrance holes. Tube has handle at mid-span and adjustable tail pipe clamp.

Filters and Sample Handling - No filters are used. Steel water trap is used in sample hose as water drop-out. It requires periodic emptying. Internal pump moves sample from vehicle to analyzer bench.

Cal Gas Inlet - Front mount, same as sample inlet.

Power Requirements - 115 VAC 60HZ 100 watts

Operating Principles - Nondispersive single beam infrared instrument using narrow band infrared optical filters. Incorporates a sample cell reference filter to cancel the effects of dust, particulates and smoke in the sample cell.

Calibration - Electronic reference signal by "calibrate check" button on front panel and calibration reference points on meter faces. Gas calibration through front panel port utilizing span adjustment screws on front panel.

Operation and Calibration - Very easy. Operating and calibrating instructions on analyzer and cart.

1. Warm up
2. Set zero
3. Push calibration check button
4. If OK, ready for use
5. If not, gas calibration through front port using HC and CO span screws.
6. Adjust calibrate check points
7. Ready for use

7.3.1 Operational Performance Comments

This unit is identical to the Mopar IIIC except for the logo. This unit was tested as an alternate to the unavailable Andros unit. The relative degree of interinstrument correlation was demonstrated by the Scott and Mopar IIIC tests.

This unit has excellent mobility while on its cart, due to C.G. location, handle placement and wheel size. In addition, the unit is very handy used as a bench top model due to its small size. The analyzer fits freely but tightly into a tilted recess at the top of the cart. The analyzer is equipped with a top-mount, strap-carrying handle that facilitates removal from the cart for portable use. The cart contains a top-mounted drawer that is handy for manual storage and a bottom storage cabinet with snap closing door. This cabinet works very well for probe, trap and sample hose storage, although hose hangers are mounted on the cart side and rear.

This analyzer uses a turbine-type sample pump differing from the typical diaphragm pump found on other analyzers. This results in a very low level of both noise and vibration.

This unit, without benefit of any form of particulate filter, has an unusual sample handling system that appears to be relatively unsusceptible to water and particulate accumulation.

This system uses only a single metal cooling tube in its sample hose to collect moisture. This tube acts as a system low point and collects condensed sample moisture which must be dumped out periodically. The probe used on this unit is a convoluted tube approximately 3 feet long. It was noted that the end plug on this sample tube broke off at the weld during durability testing. The sample hose, made of clear unreinforced plastic tubing, periodically filled with water during durability testing. When the flow restriction light indicated low flow, the hose was drained and sampling returned to normal. The material used for this hose was susceptible to melting when placed against a hot exhaust pipe.

This unit, in general, was very easy to use and demonstrated exceptional dependability. The analytical system on this unit consisted of a single sample cell and rotating filter wheel. This unit demonstrated fast response during the laboratory tests and vehicle test sequences. The response time deteriorated badly by the end of the durability tests. The cause of this deterioration might have been contamination or pump degradation.

This unit and Mopar IIIC incorporated lower ranges than any other instrument tested. Because of its extremely low range, it is more applicable for use with catalytic converter-equipped cars than the other instruments.

This instrument had a minimum number of controls and the simplest and most straightforward operation and calibration procedures.

A single front panel gas port was used for both sample and calibration gases. Range selection was made through the use of individual HC and CO toggle switches. Range indication, other than switch position, was not utilized, and this was the only negative aspect to the control/display function.

In the laboratory tests, this unit showed acceptable warm up times. Zero drift performance at normal laboratory temperature was reasonable considering the low ranges incorporated in this unit. Zero drift for CO at high temperature was 70 percent full scale indicating extreme stability sensitivity to high temperatures. Low temperature zero drift was greater than that at normal temperatures, but an order of magnitude lower for CO than that at high temperatures. (NOTE: both Scott IIIC and Mopar IIIC showed the same zero drift temperature sensitivity.)

The Scott IIIC showed good analytical accuracy tying with the Mopar IIIC for fifth most accurate overall in the accuracy determination tests. In the high altitude tests, the CO accuracy readings slipped significantly, most prominently during high range tests. (The Mopar IIIC showed the same tendency.)

Instrument response time was fast, on the order of 10 seconds or less and was relatively consistent during laboratory tests.

This instrument was not responsive to acetylene and only marginally responsive to benzene. It was most responsive to isobutylene, followed by toluene, methane and ethylene.

Voltage variation caused 1/2 percent full scale or less meter reading variation.

The HC scale was noted to be slightly responsive to CO_2 and CO. The CO meter showed 3 percent full scale response to the CO_2 sample and 1.6 to 4 percent full scale response to the NO sample during the repeatability tests. The HC scale response was not very repeatable but the CO scale response was relatively repeatable, indicating possible excessive CO response to CO_2 and NO. The CO_2 response pattern was also seen in the Mopar IIIC but the NO response was not as clear.

In the vehicle tests, the Scott IIIC was found to correlate sixth best of all instruments with the EPA bench. HC correlation seemed to cause the most trouble, especially on low range during the standard and lean modes.

This unit survived the durability test to the conclusion ending 960 hours of operation.

This corresponds to exposure levels of 809,280 ppm-hours and 528 percent-hours. The instrument showed relatively good day-to-day stability in the durability test, with an average daily span drift of 1.92 percent full scale for HC and 2.65 percent full scale for CO. Resistance to vibration and shock was good with only 3 days of shock test failure (resulting in 73 percent full scale meter variation) noted for the total durability test. This corresponds to 0.05 failures per day.

This instrument required no maintenance other than hose and trap draining during the duration of all tests. During the durability tests, the hose required draining 14 times. This corresponds to a rate of 1.46 servicings per 100 hours of operation. This was the lowest total maintenance requirement of all instruments tested.

The only detrimental effect of the durability test on this instrument was the aforementioned loss in response time.

Test data for Scott IIIC Exhaust Emission Analyzer are shown in Tables 7-11 through 7-15.

Photographs of this instrument are shown in Figures 7-8, 7-9, and 7-10.

Attachment (1)

Table 7-11. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: SCOTT IIIC

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	18	12	21	15		
	LOW	CO	16	11	21	15		
	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
ZERO DRIFT	LOW	HC	0	5.0	9.33	5.33		
	LOW	CO	2.0	70.0	6.0	1.80		
GAS INTERFERENCE (% of FS)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.66	-	0.33	0	0	0
(CYCLE 1)	LOW	CO	0	2.0	-	0	4.0	0
ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO		
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS	
CYCLE 1	HIGH	HC/CO	35	+ 3.03	+ 10	0.0	0	
	HIGH	HC/CO	70	- 1.54	- 1.05	+ 3.08	+ 2.0	
	HIGH	HC/CO	100	+ 0.23	+ 0.2	+ 3.26	+ 3.0	
	LOW	HC/CO	35	- 0.99	- 0.33	+ 1.25	+ 4.2	
	LOW	HC/CO	70	- 2.0	- 1.33	+ .07	+ .04	
	LOW	HC/CO	100	+ 1.71	+ 1.67	0.0	0	
CYCLE 2	HIGH	HC/CO	35	0	0	0	0	
	HIGH	HC/CO	70	- 5.95	- 3.05	+ 4.62	+ 3.0	
	HIGH	HC/CO	100	- 3.85	- 3.3	+ 3.26	+ 3.0	
	LOW	HC/CO	35	- 3.96	- 1.3	+ 0.06	+ 0.2	
	LOW	HC/CO	70	- 4.0	- 2.67	- 0.28	- .16	
	LOW	HC/CO	100	- 1.36	- 1.3	+ 2.0	+ 2.0	

Table 7-11. DATA COMPOSITE - LABORATORY TEST (Cont'd)

SCOTT IIIC

CYCLE 3	HIGH	HC/CO	35	+ 4.54	+ 1.50	- 1.88	- 0.7
	HIGH	HC/CO	70	- 2.65	- 1.8	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.93	- 0.8	+ 2.17	+ 2.0
	LOW	HC/CO	35	- .99	- .33	+ 1.25	+ .42
	LOW	HC/CO	70	0	0	+ .76	+ .44
	LOW	HC/CO	100	+ 2.05	+ .20	+ 2.0	+ 2.0
CYCLE 4	HIGH	HC/CO	35	+ 4.54	+ 1.50	- .54	- 0.2
	HIGH	HC/CO	70	- 1.18	- 0.8	+ 3.08	+ 2.0
	HIGH	HC/CO	100	+ .23	+ 0.2	+ 2.17	+ 2.0
	LOW	HC/CO	35	+ 3.96	+ 1.33	+ 1.25	+ .42
	LOW	HC/CO	70	0	0	+ 0.41	+ .24
	LOW	HC/CO	100	+ 4.10	+ 4.0	+ 1.0	+ 1.0
HIGH ALTITUDE	HIGH	HC/CO	35	- 1.51	- 0.5	-16.66	- 6.2
	HIGH	HC/CO	70	- 8.15	- 5.55	-16.92	-11
	HIGH	HC/CO	100	- 6.76	- 5.8	-18.48	-17
	LOW	HC/CO	35	- 1.98	- .67	-11.85	- 3.98
	LOW	HC/CO	70	- 1.0	- .67	-17.18	- 9.96
	LOW	HC/CO	100	+ 0.68	+ .67	-12.0	-12.0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1647	10.1	9.75	8.25	6.05
	HIGH	CO	8.1	9.5	9.5	7.0	6.0

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	2	7	86	16	38
6750 Feet Altitude	LOW	0	0	7	78	13	38

Table 7-11. DATA COMPOSITE - LABORATORY TEST (Cont'd)

SCOTT IIIC

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0.5	0
	115V	HIGH	CO	0	0

Table 7-12. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **SCOTT IIIC**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	**HC**	15	29	25	25		
	LOW	**CO**	12	27	27	22		
ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	**HC**	5.0	12.6	3.66	1.6		
	LOW	**CO**	2.4	2.0	4.6	1.0		
GAS INTERFERENCE (% of FS) **CYCLE 1**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	0.67	0.0	0.0	0.0
	LOW	**CO**	3.0	2.0	-	0.0	4.0	1.0
GAS INTERFERENCE (% of FS) **CYCLE 2**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	0	0	0	0
	LOW	**CO**	3.0	0	-	0	2.0	0
GAS INTERFERENCE (% of FS) **CYCLE 3**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	0	0	0	0
	LOW	**CO**	3.6	0	-	0	1.6	0
GAS INTERFERENCE (% of FS) **CYCLE 4**	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	**HC**	0	-	0.3	0	0	0
	LOW	**CO**	0	-	-	0	2.4	0
RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)				
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)	
	HIGH	**HC**	1647	21.5	13.5	9	10.5	
	HIGH	**CO**	8.1	21.5	13.5	7	8.5	

Table 7-12. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

SCOTT IIIC

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+3.03	+1.00	-1.88	-0.70
	HIGH	HC/CO	70	-2.65	-1.80	+1.54	+1.00
	HIGH	HC/CO	100	+0.23	+0.20	+2.17	+2.00
	LOW	HC/CO	35	+1.98	+0.67	+4.23	+1.42
	LOW	HC/CO	70	-0.50	-0.33	+0.07	+0.04
	LOW	HC/CO	100	+1.02	+1.00	+2.00	+2.00
CYCLE 2	HIGH	HC/CO	35	+6.06	+2.0	-1.88	-0.7
	HIGH	HC/CO	70	-1.91	-1.3	+1.54	-1.0
	HIGH	HC/CO	100	+0.23	+0.2	+3.26	+3.0
	LOW	HC/CO	35	+1.98	+0.6	+1.19	+0.4
	LOW	HC/CO	70	+0.5	+0.3	-0.62	-0.36
	LOW	HC/CO	100	+2.38	+2.3	+2.0	+2.0
CYCLE 3	HIGH	HC/CO	35	+6.82	+2.25	-3.23	-1.2
	HIGH	HC/CO	70	-1.54	-1.05	+1.54	+1.0
	HIGH	HC/CO	100	+1.11	+0.95	+1.09	+1.0
	LOW	HC/CO	35	0	0	+0.66	+0.22
	LOW	HC/CO	70	-0.5	-0.33	-0.62	-0.36
	LOW	HC/CO	100	+2.05	+2.0	+0.6	+0.6
CYCLE 4	HIGH	HC/CO	35	+6.82	+2.25	-2.69	-1.00
	HIGH	HC/CO	70	-1.54	-1.05	+1.85	+1.20
	HIGH	HC/CO	100	+0.52	+0.45	+2.17	+2.0
	LOW	HC/CO	35	-0.99	-0.33	-5.36	-1.80
	LOW	HC/CO	70	-1.00	-0.67	-5.52	-3.20
	LOW	HC/CO	100	+1.71	+1.67	-2.00	-2.0

Table 7-13. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

SCOTT IIIC

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC % ERROR ABSOLUTE	HC % ERROR FS	CO % ERROR ABSOLUTE	CO % ERROR FS
STANDARD MODE CYCLE 1	300/10	HC/CO	50	- 30.82	- 10.1	- 10.45	- 0.7
	300/.5	HC/CO	30	- 30.85	- 11.6	- 28.57	- 8.0
	300/10	HC/CO	IDLE	- 5.21	- 3.67	+ 7.14	+ 1.0
CYCLE 2	300/.5	HC/CO	50	- 21.05	- 6.4	- 13.79	- 0.8
	300/.5	HC/CO	30	- 31.74	- 12.4	- 46.88	- 15.0
	300/10	HC/CO	IDLE	- 10.09	- 8.6	- 1.79	- 0.2
CYCLE 3	300/.5	HC/CO	50	- 11.50	- 3.77	- 16.67	- 1.0
	300/.5	HC/CO	30	- 0.48	- 0.17	- 35.71	- 10.0
	300/10	HC/CO	IDLE	+ 12.66	+ 7.87	+ 13.92	+ 2.2
CYCLE 4	300/10	HC/CO	50	- 33.65	- 11.83	- 14.71	- 1.0
	300/.5	HC/CO	30	- 30.85	- 11.6	+ 13.64	+ 3.0
	2000/.5	HC/CO	IDLE	- 28.17	- 24.83	+ 3.17	+ 0.4
LEAN MODE CYCLE 1	300/10	HC/CO	50	- 38.83	- 14.6	- 6.78	- 0.4
	300/.5	HC/CO	30	- 37.05	- 11.97	- 26.92	- 7.0
	300/10	HC/CO	IDLE	+ 13.71	+ 4.07	- 19.05	- 8.0
CYCLE 2	300/10	HC/CO	50	- 19.5	- 6.3	+ 7.14	+ 0.4
	300/.5	HC/CO	30	- 16.58	- 5.43	- 10.0	- 2.0
	300/10	HC/CO	IDLE	+ 22.73	+ 4.26	+ 16.67	+ 10.0
CYCLE 3	300/10	HC/CO	50	- 1.96	- 0.63	- 11.69	- 0.9
	300/.5	HC/CO	30	- 1.8	- 0.6	- 16.67	- 4.0
	300/10	HC/CO	IDLE	- 6.35	- 9.0	+ 27.66	+ 1.3
CYCLE 4	300/10	HC/CO	50	- 37.06	- 13.93	- 14.06	- 0.9
	300/.5	HC/CO	30	- 38.06	- 14.13	- 29.17	- 7.0
	2000/10	HC/CO	IDLE	- 5.1	- 0.94	- 5.26	- 4.0

Table 7-13. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

SCOTT IIIC

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	300/10	HC/CO	50	- 1.96	- 0.63	0	0
	300/.5	HC/CO	30	- 6.28	- 2.3	- 12.5	- 3.0
	300/10	HC/CO	IDLE	- 2.67	- 2.3	+ 5.92	+ 1.9
CYCLE 2	300/10	HC/CO	50	+ 3.2	+ 1.03	- 6.78	- 0.4
	300/.5	HC/CO	30	- 2.21	- 0.8	- 29.17	- 7.0
	300/10	HC/CO	IDLE	+ 4.02	+ 3.8	+ 14.86	+ 5.5
CYCLE 3	300/10	HC/CO	50	- 4.67	- 1.67	- 11.29	- 0.7
	300/.5	HC/CO	30	- 11.35	- 4.27	+ 50.0	+ 10.0
	300/10	HC/CO	IDLE	- 2.16	- 2.1	+ 12.27	+ 4.7
CYCLE 4	300/10	HC/CO	50	- 7.11	- 2.5	- 18.18	- 1.0
	300/.5	HC/CO	30	- 14.24	- 5.7	+ 15.38	+ 4.0
	2000/10	HC/CO	IDLE	- 10.05	- 1.57	+ 6.64	+ 2.8

Table 7-14. DIAGNOSTIC TEST

SCOTT IIIC

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1025	1131	- 9.37	- 5.3
	10%	CO	2.60	2.11	+ 23.22	+ 4.9
NORMAL IDLE	300	HC	270	390	- 30.77	- 4.0
	10%	CO	2.60	2.14	+ 21.50	+ 4.6
IGNITION ADVANCE	2000	HC	310	349.1	- 11.20	- 1.96
	10%	CO	2.70	2.19	+ 23.29	+ 5.1
IGNITION RETARD	300	HC	250	365.9	- 31.68	- 38.63
	10%	CO	2.80	2.43	+ 15.23	+ 3.7

Table 7-15. DURABILITY TEST DATA

INSTRUMENT: SCOTT IIIC

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	960
HC EXPOSURE (PPM-HRS.)	809,280
CO EXPOSURE (%-HRS.)	528
NO EXPOSURE (PPM-HRS.)	114,240
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	3
SHOCK TEST FAILURE RATE (Failure/Day %)	5.0
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	2
HC SPAN	0
CO ZERO	0
CO SPAN	1
AVERAGE DAILY SPAN DRIFT	
HC%	1.92
CO%	2.65
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	--
PER 100 HRS.	--
B DRAIN HOSE	
TOTAL	14
PER 100 HRS.	1.46
C REZERO	
TOTAL	--
PER 100 HRS.	--
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	--
PER 100 HRS.	--

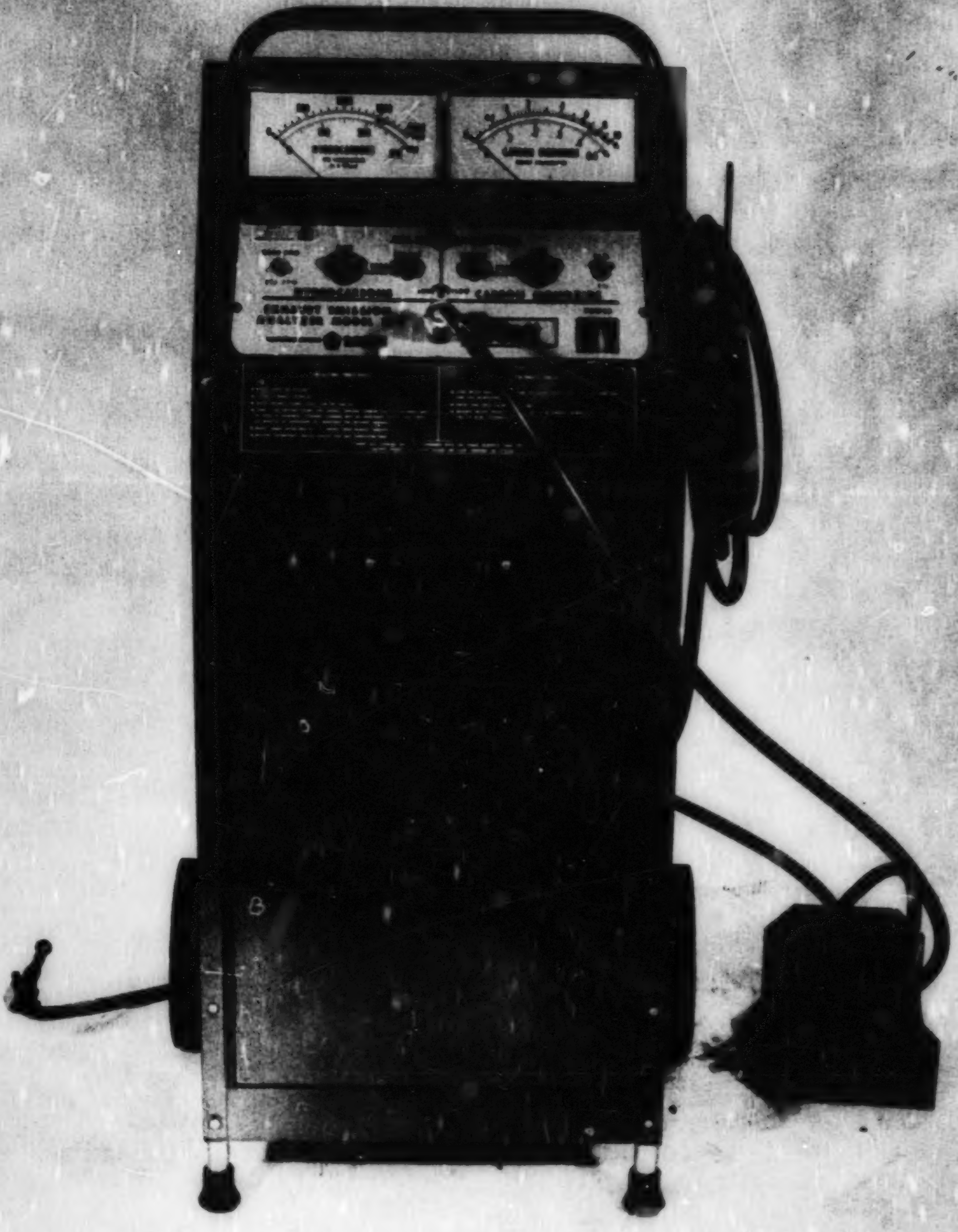

Figure 7-8. SCOTT IIIC EXHAUST EMISSION ANALYZER

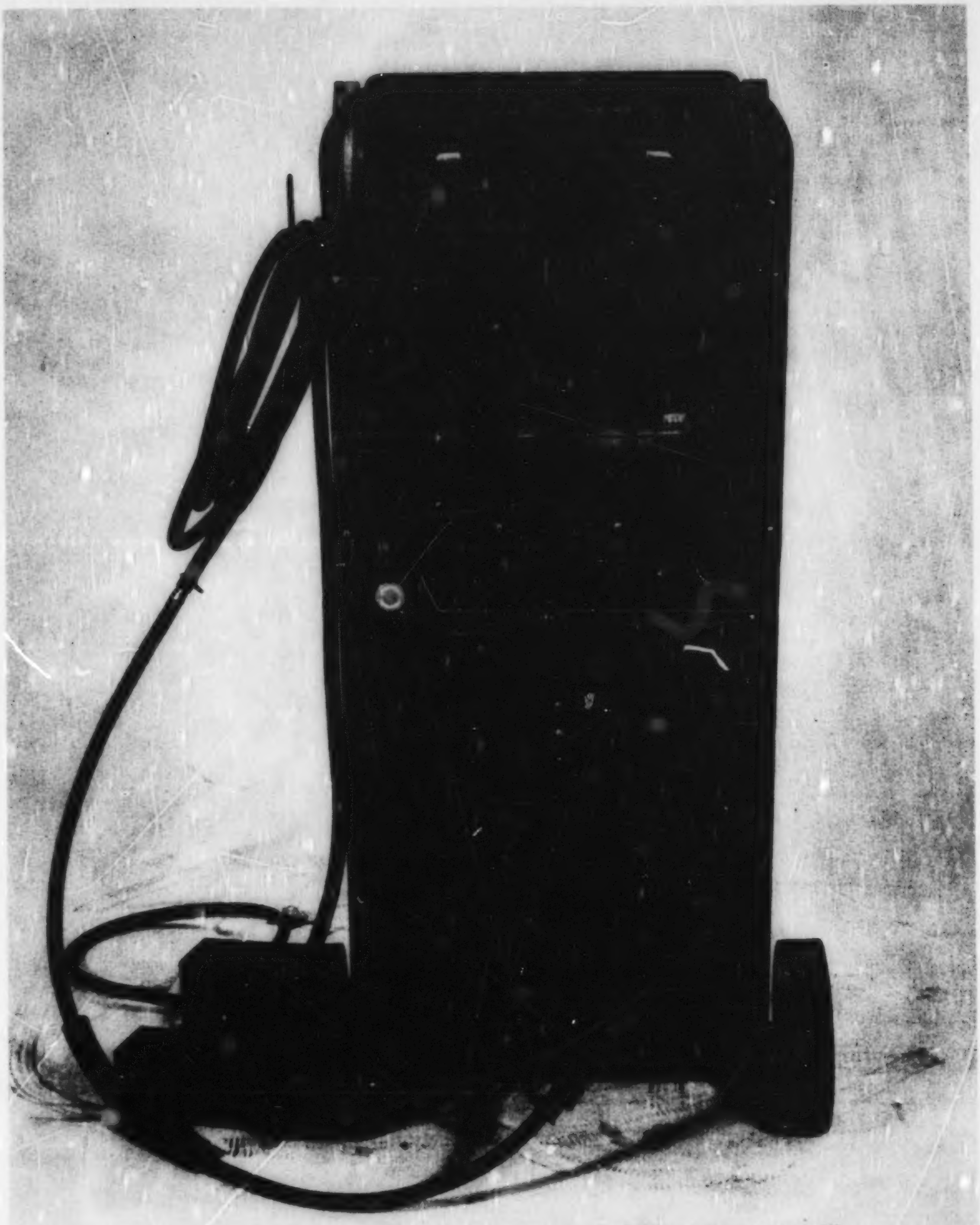

Figure 7-9. SCOTT IIIC EXHAUST EMISSION ANALYZER (BACK)

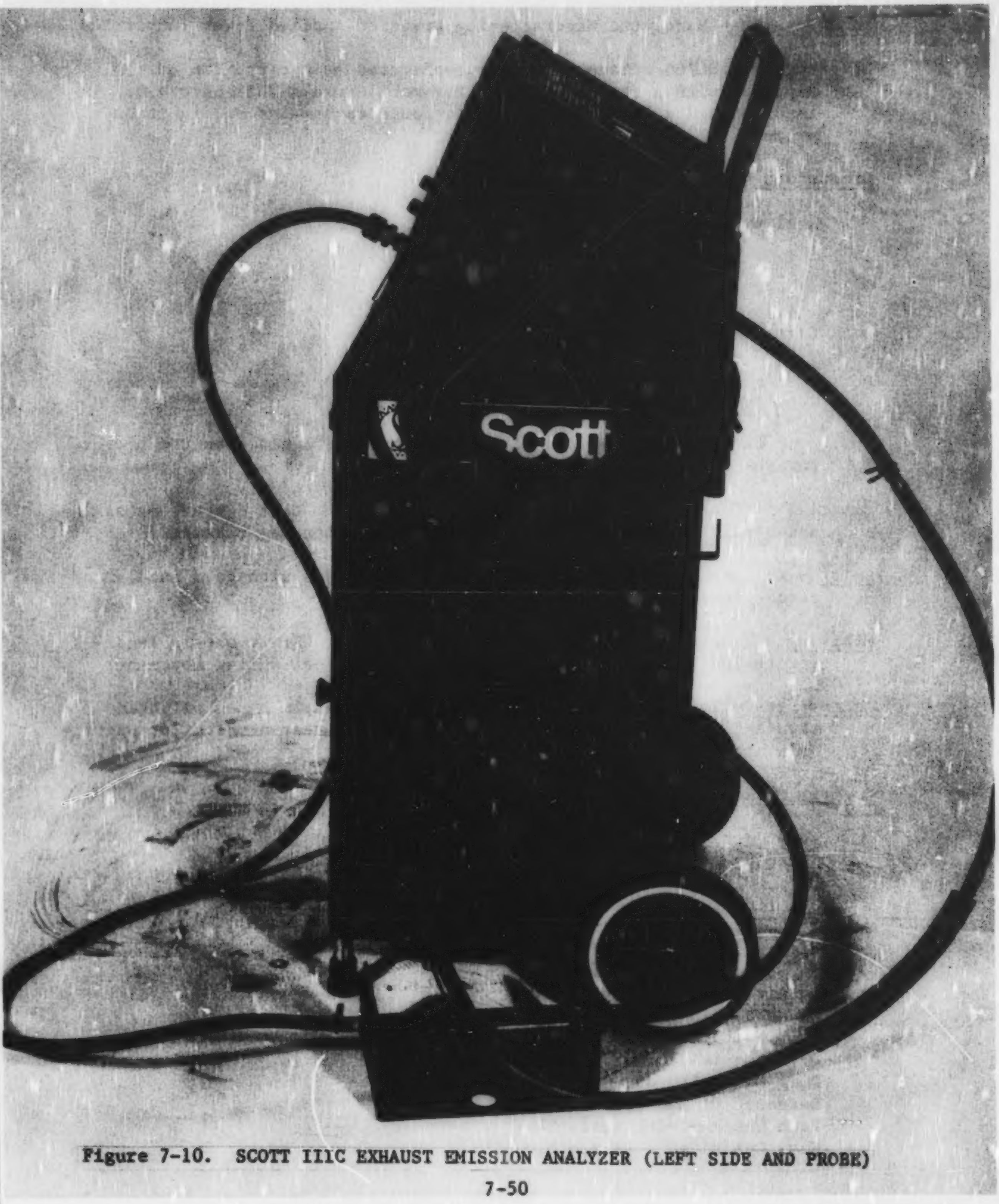

Figure 7-10. SCOTT IIIC EXHAUST EMISSION ANALYZER (LEFT SIDE AND PROBE)

7.4 MARQUETTE 42-160 INFRARED EMISSIONS ANALYZER

Manufacturer - Marquette Manufacturing Division Applied Power Industries

Description - HC/CO exhaust analyzer configured as a bench top unit supplied with a four-wheel cart for mobile use. This unit also incorporated a 0 to 3,000 rpm electronic tachometer and ignition probe.

Dimensions -

Analyzer: Height - 17-3/4 inches
Width - 13-1/2 inches
Length - 23-5/8 inches
Weight - 80 lbs.

Cart: Height - 34 inches
Width - 19 inches
Length - 27-1/2 inches
Weight - 50 lbs.

Cart has one lower shelf for storage and a side-mounted hanger for the sample hose.

Material of Construction - Analyzer - Sheet metal. Cart - Sheet metal and steel tubing. Joints are welded and/or screwed together.

Color - Analyzer - Red with black front. Cart - Red with gold handle and chrome tube legs.

Mobility - Four steerable, 4-inch diameter wheels. Front wheels incorporate locks. Mobility is good with stable feel during movement.

Accessories - Tail pipe probe, flexible 20-foot sample hose, weighted shot bag (to hold probe in tail pipe), tachometer probe wire, operator's manual.

Control Package -

Front Access - Test mode switch (four positions)
1. Tach, CO-LO
2. CO/HC HI
3. CO/HC LO
4. Span
HC Air adjust - knob (zero)
HC Span adjust - knob
CO Air adjust - knob (sero)
CO Span adjust - knob
Pump Switch - ON/OFF toggle
Detector Switch -ON/OFF toggle
Pump On Indicator - light
Detector On Indicator - light
Tach Check - push button
Fuse Cartridge - 4A slo blo

Side Access -
HC - Span (scale) - screw
HC - High (scale) - screw
CO - Span (scale) - screw
CO - High (scale) - screw

Located on right panel under a small plate attached with two screws.

Mode Switch - (pneumatic) - 2-position - sample, air/cal gas (located on left panel)
Flow indicator - mechanical
Air/cal gas inlet

Meters - 7-3/4" wide x 4-5/8" high, 100° swing

Black figures and increments on white background Figures on meter faces were large giving very good long range readability. HC meter incorporates 0 to 3,000 rpm tach scale on bottom of meter.

HC scale - 0 - 2000 ppm in 20 ppm increments
0 - 1000 ppm in 10 ppm increments
CO scale - 0 - 10% in 0.20% increments
0 - 5% in 0.10% increments

These meters did not appear to be sensitive to static electricity (soft cloth rubbed across meter face).

Altitude Compensation - On chart in operator's manual. No scale on meter faces. Not needed if gas calibrated at altitude used.

Probe - "S" curved tubing with a spiral flex section welded on the top of the tube. A convoluted tube is inserted into the flexible section. The sampling tip is on the end of the convoluted tube.

Filters and Sample Handling - Pump aspirated water trap (self draining) with level routing of water outlet. A large accordion-type circular paper filter cartridge was in series with water trap. Mechanical flow indicator.

Cal Gas Inlet - Side panel near flow mode switch.

Power Requirements - 120 volts 60HZ 360 watts

Operating Principles - Dual beam nondispersive infrared with chopper, positive filters, solid-state detectors, and hot wire sources.

Calibration - Electronic span adjust on meter faces with mode switch in span. Gas calibration with side port and side-mounted adjustment screws. Multiple turn pots for zero and span give good range and resolution.

Operation and Calibration - Fairly straightforward, but combined range and function switch was slightly confusing.

1. Set air adjust (zero)
2. Check mechanical span
3. Run low and then high range gases using front span adjust and side "High" pots
4. Using side "Span" pots adjust span set point
5. Push tach check button - needle to tach set dot
6. Ready for use

7.4.1 Operational Performance Comments

The analyzer and cart combination is relatively heavy. The analyzer sets freely on the top of the cart and is configured as a bench top unit, but at 80 pounds it is really too heavy to be a practical bench top analyzer. The lower shelf on the cart works well for storage of the probe and sample hose. The engine rpm function included on this unit could be a very useful accessory. The control of this function with the same mode switch used for emission measurements was slightly confusing.

From a functional standpoint, the sample system and, specifically, the paper filter cartridge was probably the best filter design of all units tested that used filters. It presented the fewest maintenance problems of all filters. The mechanical flow indicator used in this unit gave better progressive indication of flow degradation than the on/off light types, although the mechanical indicator was not as obvious as a light.

There were good operating instructions on the instrument case but they were located in a relatively awkward position on the left side panel of the unit. There were no calibration instructions on the unit, but they were included in the operator's manual.

This instrument utilized a relatively stiff sample hose that exhibited ply separation at both ends by the conclusion of the durability test. In addition, during the durability test, the probe failed at the beginning of the flex section. The spiral flex section broke near its weld.

In the laboratory tests this unit showed fairly long warm up times at normal temperatures This unit demonstrated extreme up- and down-scale zero drift for several hours after warm up. Due to the test data collection technique (one data point taken every 30 minutes for 4 hours), this phenomenon was not terribly apparent. Many times the meter needle position at data collection time was near zero while, in reality, the needle subject to randomly occurring erratic zero and span shifts during the laboratory tests. Poor performance in some tests can be attributed to this phenomenon. This phenomenon was somewhat similar to accelerated zero or span drift. Zero drift performance indicated by the data showed 3 percent full scale drift on HC as the worst case.

Gas interference showed 1 percent full scale or less meter deflection for all gases.

The Marquette was second only to Horiba in overall accuracy. Its overall accuracy was very good. In high altitude accuracy tests the Marquette scored highest of all HC/CO analyzers.

The general response time for this unit was slow, ranging up to 30 seconds. Pump sizing or sample system design may have been at fault.

This unit showed no HC response to acetylene or benzene. It was most responsive to isobutylene followed by toluene. It was marginally responsive to ethylene and methane. Voltage fluctuation caused 1 percent full scale or less meter deflection.

In the repeatability drift test, the random erratic shifts noted early can be seen to detrimentally affect the performance data.

In the vehicle tests, the Marquette was found to correlate second best to the EPA bench. No real problem areas were evident in exhaust correlation. This instrument survived the durability tests to the end. It endured 960 hours of operation. This corresponded to an exposure level of 809,280 ppm-hours for HC and 528 percent-hours for CO. Although it finished the test, its operation was deteriorating rapidly at the end.

The design of this instrument's sample system incorporates a restrictor plug in the aspirator near the water outlet. This restrictor plug stopped up often, requiring shut down, removal of sample hose, water trap top cover and other miscellaneous hoses and subsequent cleaning.

Durability tests indicated that the paper filter used on this unit had a long, trouble-free life. Maintenance of this filter was quick and simple due to its external location.

In the shock and vibration test, the unit totalled 11 test days when 3 percent variation was noted during this test. This indicates moderate sensitivity to shock. This corresponds to 0.18 failures per day.

The average daily span drift noted during durability tests was 5.7 percent full scale for HC and 4.9 percent full scale for CO indicating that span set adjustments are needed more often than on a daily basis.

In general, overall service requirements for this unit were about average considering all test units.

Test data for Marquette 42-160 Infrared Emission Analyzer are shown in Tables 7-16 through 7-20.

Photographs of this instrument are shown in Figures 7-11, 7-12, and 7-13.

Table 7-16. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: MARQUETTE 42-160

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	23	14	27	15		
	LOW	CO	23	14	27	9		
ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	0.5	2.0	3.0	0		
	LOW	CO	0	1.0	0.4	0.2		
GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0.2	0	0	0
	LOW	CO	0	0	-	0	0	0
ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO		
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS	
CYCLE 1	HIGH	HC/CO	35	+ 3.70	+ 1.25	+ 1.61	+ 0.60	
	HIGH	HC/CO	70	- 0.65	- 0.45	+ 1.69	+ 1.10	
	HIGH	HC/CO	100	+ 0.23	+ 0.20	- 0.98	- 0.90	
	LOW	HC/CO	35	- 1.12	- 0.40	+ 2.86	+ 1.00	
	LOW	HC/CO	70	- 0.44	- 0.30	- 0.96	- 0.60	
	LOW	HC/CO	100	- 2.60	- 2.2	- 0.96	- 0.80	
CYCLE 2	HIGH	HC/CO	35	+ 9.63	+ 3.25	+ 2.15	+ 0.8	
	HIGH	HC/CO	70	- 2.23	- 1.55	+ 2.31	+ 1.5	
	HIGH	HC/CO	100	- 0.80	- 0.70	0	0	
	LOW	HC/CO	35	- 0.56	- 0.20	+ 0.57	+ 0.20	
	LOW	HC/CO	70	- 2.22	- 1.50	+ 3.21	+ 2.00	
	LOW	HC/CO	100	- 7.57	- 6.40	+ 5.78	+ 4.80	

Table 7-16. DATA COMPOSITE - LABORATORY TEST (Cont'd)

MARQUETTE 42-160

CYCLE 3	HIGH	HC/CO	35	+ 6.67	+ 2.25	+ 0.81	+ 0.30
	HIGH	HC/CO	70	- 0.07	- 0.05	+ 1.54	+ 1.00
	HIGH	HC/CO	100	+ 0.23	- 0.20	+ 0.54	+ 0.50
	LOW	HC/CO	35	+ 2.24	+ 0.80	- 2.86	- 1.00
	LOW	HC/CO	70	+ 2.22	+ 1.50	+ 0.96	+ 0.60
	LOW	HC/CO	70	+ 2.22	+ 1.50	+ 0.96	+ 0.60
CYCLE 4	LOW	HC/CO	100	- 1.89	- 1.60	0	0
	HIGH	HC/CO	36	+ 0.74	+ 0.25	- 0.54	- 0.20
	HIGH	HC/CO	70	- 0.79	- 0.55	+ 1.54	+ 1.0
	HIGH	HC/CO	100	+ 0.34	+ 0.3	- 1.09	- 1.0
	LOW	HC/CO	35	- 0.56	- 0.20	- 1.14	- 0.40
	LOW	HC/CO	70	- 0.74	- 0.50	- 0.64	- 0.40
HIGH ALTITUDE	LOW	HC/CO	100	- 3.07	- 2.60	- 1.21	- 1.00
	HIGH	HC/CO	35	+ 3.07	+ 1.25	- 1.88	- 0.70
	HIGH	HC/CO	70	- 2.23	- 1.55	0	0
	HIGH	HC/CO	100	+ 0.34	+ 0.30	- 1.09	- 1.00
	LOW	HC/CO	35	- 1.96	- 0.70	- 1.71	- 0.60
	LOW	HC/CO	70	- 0.74	- 0.50	+ 0.96	+ 0.60
RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1683	14.45	11.5	30.0	25.0
	HIGH	CO	8.1	14.9	12.75	28.5	26.5
HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	5	78	5	21
6750 Feet Altitude	LOW	0	0	5	84	20	28

Table 7-16. DATA COMPOSITE - LABORATORY TEST (Cont'd)

MARQUETTE 42-160

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0.65	0.65
	115V	HIGH	CO	1.0	1.0

Table 7-17. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **MARQUETTE 42-160**

	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
WARMUP TIME (Min.)	LOW	HC	8	28	24	20
	LOW	CO	8	27	17	14

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	15.0	8.4	4.4	5.9
	LOW	CO	0.6	0.6	0.2	0.2

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 1	LOW	HC	0.0	-	0.5	0.0	0.0	0.0
	LOW	CO	0.2	1.0	-	-	0.0	0.0

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 2	LOW	HC	0	-	0.5	0	0	0
	LOW	CO	0.4	0	-	0	0	0.2

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 3	LOW	HC	0	-	0	0	0	0
	LOW	CO	0.4	0	-	0	0	0

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 4	LOW	HC	0	-	0190	0	0	0
	LOW	CO	0	0	-	0	.02	0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1683	20	27.5	11.5	13.5
	HIGH	CO	8.1	21	25	10.5	8.5

Table 7-17. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

MARQUETTE 42-160

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+5.19	+1.75	-5.91	-2.20
	HIGH	HC/CO	70	-0.07	-0.05	-3.08	-2.00
	HIGH	HC/CO	100	-0.23	-0.20	-5.43	-5.00
	LOW	HC/CO	35	-0.56	-0.20	+2.29	+0.80
	LOW	HC/CO	70	-2.22	-1.50	+4.17	+2.60
	LOW	HC/CO	100	-8.98	-7.60	+3.13	+2.60
CYCLE 2	HIGH	HC/CO	35	+8.15	+2.75	+2.15	+0.8
	HIGH	HC/CO	70	-1.87	-1.3	0	0
	HIGH	HC/CO	100	-0.23	-0.2	-2.17	-2.0
	LOW	HC/CO	35	+3.08	+1.1	-2.86	-1.0
	LOW	HC/CO	70	+2.22	+1.5	+2.88	+1.8
	LOW	HC/CO	100	-3.31	-2.8	+3.13	+2.6
CYCLE 3	HIGH	HC/CO	35	+11.11	+3.75	+2.69	+1.00
	HIGH	HC/CO	70	+2.80	+1.95	+3.85	+2.50
	HIGH	HC/CO	100	+1.48	_1.3	-0.54	-0.50
	LOW	HC/CO	35	+2.24	+0.80	-3.43	-1.20
	LOW	HC/CO	70	+1.04	+0.70	-1.28	-0.80
	LOW	HC/CO	100	-1.89	-1.50	0	0
CYCLE 4	HIGH	HC/CO	35	+4.44	+1.50	-3.23	-1.20
	HIGH	HC/CO	70	-2.59	-1.80	-1.54	-1.0
	HIGH	HC/CO	100	+ 0.34	+0.30	-1.63	-1.50
	LOW	HC/CO	35	+1.40	+0.50	-1.71	-0.60
	LOW	HC/CO	70	+0.74	+0.50	+1.28	+0.80
	LOW	HC/CO	100	-4.49	-3.80	+0.48	+0.40

Table 7-18. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

MARQUETTE 42-160

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	1000/5	HC/CO	50	+ 16.99	+ 1.67	- 20.63	- 2.6
	1000/5	HC/CO	30	+ 21.5	+ 2.7	- 25.0	- 0.6
	1000/5	HC/CO	IDLE	+ 6.95	+ 1.95	+ 11.11	+ 1.0
CYCLE 2	1000/5	HC/CO	50	- 1.32	- 0.12	- 9.09	- 1.2
	1000/5	HC/CO	30	- 7.75	- 0.84	- 35.71	- 1.0
	1000/5	HC/CO	IDLE	- 4.92	- 1.19	+ 25.0	+ 5.2
CYCLE 3	1000/5	HC/CO	50	+ 20.61	+ 1.88	+ 16.07	+ 1.8
	1000/5	HC/CO	30	+ 18.48	+ 1.95	- 25.0	- 0.6
	1000/5	HC/CO	IDLE	- 33.28	- 7.74	+ 30.14	+ 4.4
CYCLE 4	1000/5	HC/CO	50	+ 4.17	+ 0.38	+ 20.0	+ 2.0
	1000/5	HC/CO	30	+ 5.21	+ 0.52	+700.0	+ 1.4
	1000/5	HC/CO	IDLE	+ 2.09	+ 0.4	+ 20.69	+ 4.8
LEAN MODE CYCLE 1	1000/5	HC/CO	50	+ 10.58	+ 0.89	+ 3.45	+ 0.4
	1000/5	HC/CO	30	+ 12.39	+ 0.99	- 18.18	- 0.4
	1000/5	HC/CO	IDLE	+ 25.31	+ 16.16	- 36.84	- 1.4
CYCLE 2	1000/5	HC/CO	50	+ 4.27	+ 0.45	- 1.79	- 0.2
	1000/5	HC/CO	30	+ 56.7	+ 0.59	- 20.0	- 0.4
	1000/5	HC/CO	IDLE	+ 6.35	+ 3.61	+ 19.05	+ 0.8
CYCLE 3	1000/5	HC/CO	50	+ 23.22	+ 2.45	+ 14.55	+ 1.6
	1000/5	HC/CO	30	+ 51.15	+ 4.23	- 15.0	- 0.3
	1000/5	HC/CO	IDLE	+ 21.88	+ 11.49	- 22.22	- 0.8
CYCLE 4	1000/5	HC/CO	50	+ 18.91	+ 1.59	+ 31.0	+ 1.6
	1000/5	HC/CO	30	+ 18.91	+ 1.67	+700.0	+ 1.4
	1000/5	HC/CO	IDLE	- 1.49	- 0.53	+ 71.43	+ 3.0

Table 7-18. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

MARQUETTE 42-160

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	1000/5	HC/CO	50	- 11.21	- 1.2	+ 8.11	+ 1.2
	1000/5	HC/CO	30	- 3.69	- 0.46	- 40.74	- 2.2
	1000/5	HC/CO	IDLE	+ 18.1	+ 6.13	- 31.03	- 28.8
CYCLE 2	1000/5	HC/CO	50	+ 28.46	+ 2.88	+ 1.69	+ 0.2
	1000/5	HC/CO	30	+ 37.44	+ 3.95	- 28.57	- 0.8
	1000/5	HC/CO	IDLE	+ 27.83	+ 8.49	+ 19.35	+ 15.4
CYCLE 3	1000/5	HC/CO	50	+ 13.25	+ 1.17	+ 7.14	+ 0.8
	1000/5	HC/CO	30	+ 23.84	+ 2.31	- 25.0	- 0.6
	1000/5	HC/CO	IDLE	+ 14.18	+ 3.54	+ 9.28	+ 6.2
CYCLE 4	1000/5	HC/CO	50	+ 9.65	+ 0.88	+ 2.94	+ 0.4
	1000/5	HC/CO	30	+ 9.00	+ 0.95	- 38.46	- 1.0
	1000/5	HC/CO	IDLE	- 25.57	- 6.7	- 27.78	- 20.0

Table 7-19. DIAGNOSTIC TEST

MARQUETTE 42-160

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	1000	HC	1025	1131	- 19.64	+ 22.0
	5%	CO	2.70	2.17	+ 24.42	+ 10.6
NORMAL IDLE	1000	HC	740	669	+ 10.61	+ 7.1
	5%	CO	2.70	2.20	+ 22.73	+ 10.0
IGNITION ADVANCE	1000	HC	700	660	+ 6.06	+ 4.0
	5%	CO	2.80	2.22	+ 26.13	+ 11.6
IGNITION RETARD	1000	HC	520	496	+ 4.84	+ 2.4
	5%	CO	2.75	220	+ 2.5	+ 11.0

Table 7-20. DURABILITY TEST DATA

INSTRUMENT: MARQUETTE 42-160

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	960
HC EXPOSURE (PPM-HRS.)	809,280
CO EXPOSURE (%-HRS.)	528
NO EXPOSURE (PPM-HRS.)	114,240
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	11
SHOCK TEST FAILURE RATE (Failure/Day %)	18.33
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	11
HC SPAN	1
CO ZERO	1
CO SPAN	0
AVERAGE DAILY SPAN DRIFT	
HC%	5.65
CO%	4.86
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	6
PER 100 HRS.	0.63
B DRAIN HOSE	
TOTAL	21
PER 100 HRS.	2.19
C REZERO	
TOTAL	54
PER 100 HRS.	5.63
D. SAMPLING SYSTEM	
TOTAL	17
PER 100 HRS.	1.77
E. OTHER	
TOTAL	51*
PER 100 HRS.	5.31

* SWITCHED TO AIR INLET TO BLOW OUT WATER TRAP

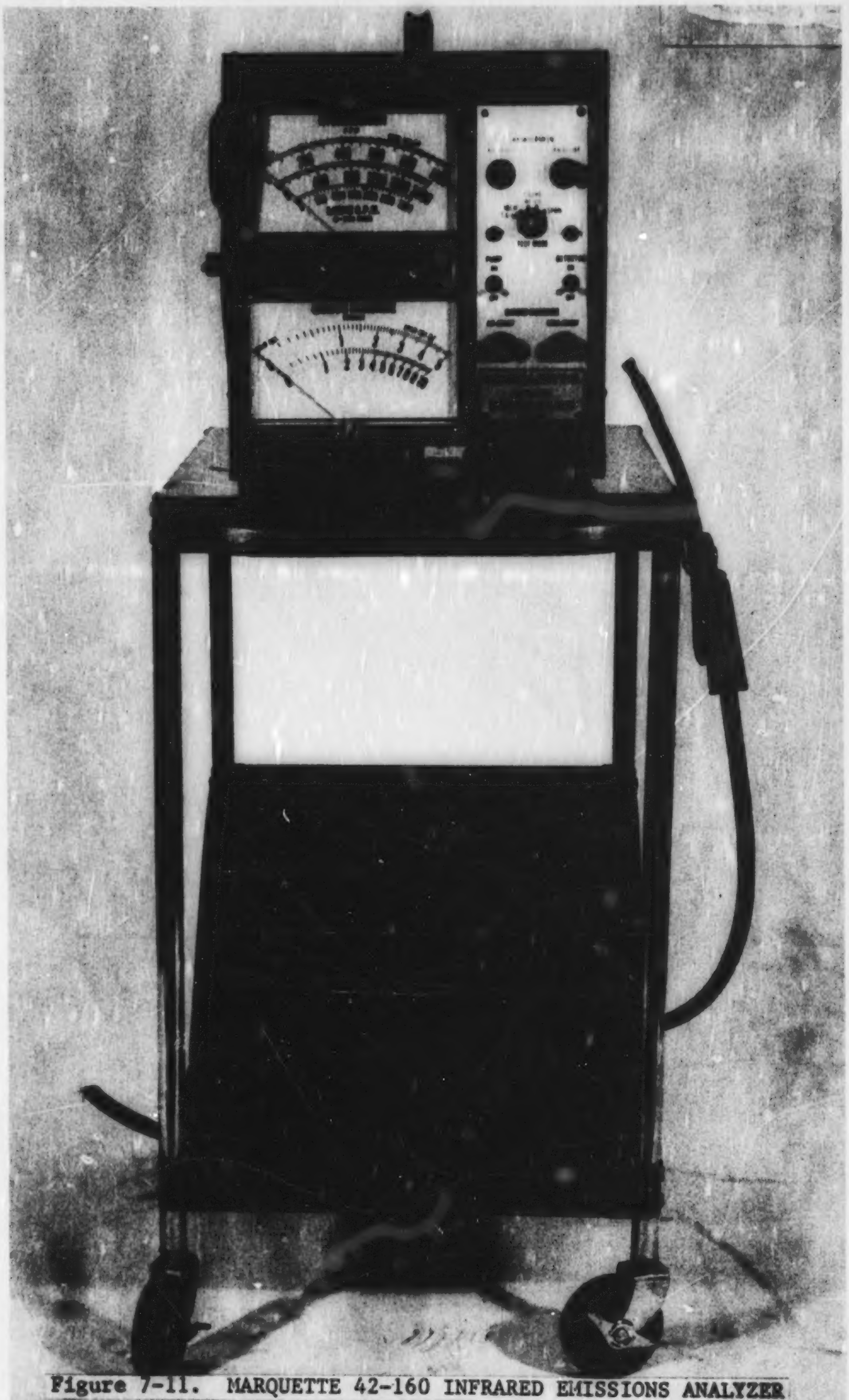

Figure 7-11. MARQUETTE 42-160 INFRARED EMISSIONS ANALYZER

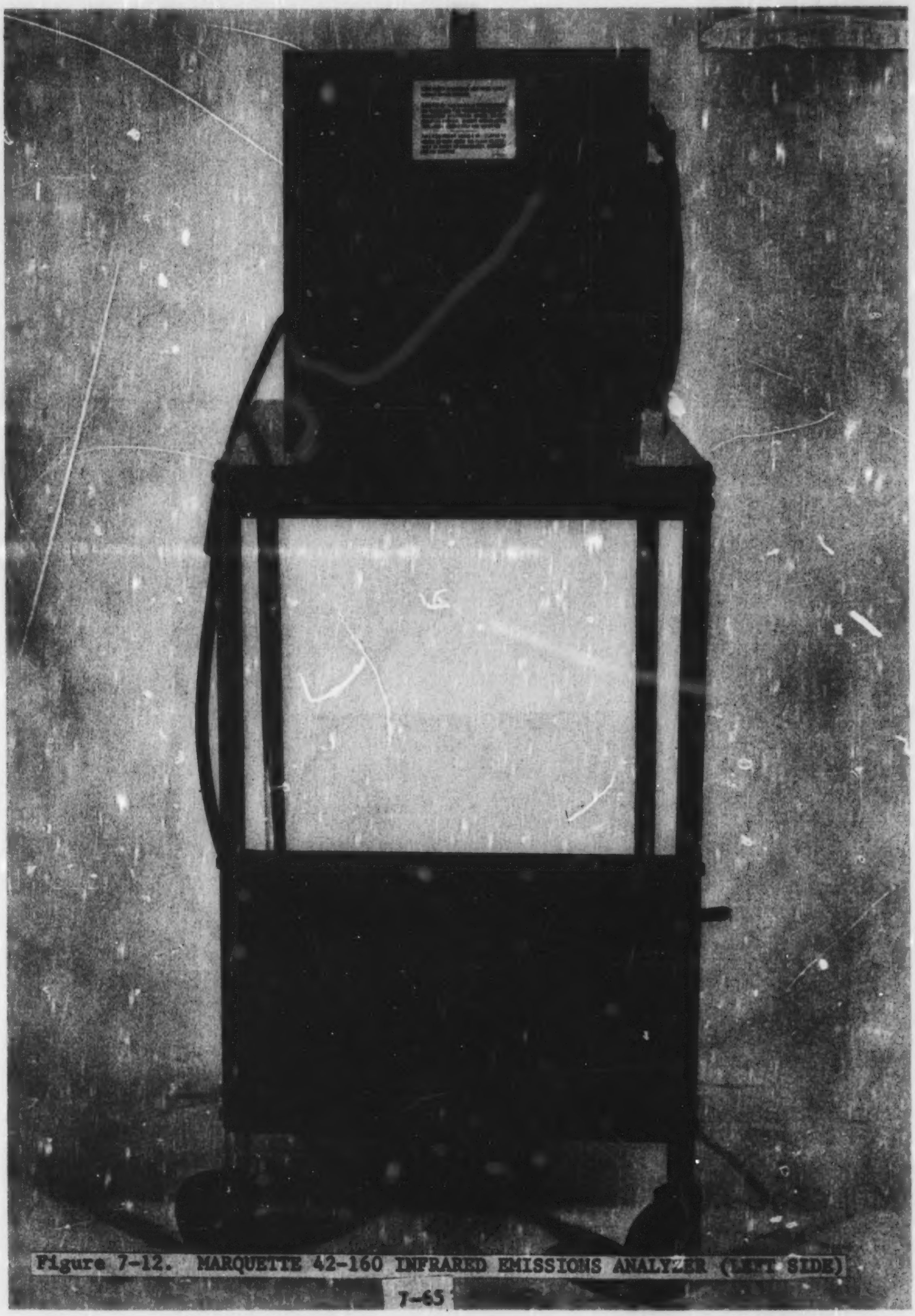

Figure 7-12. MARQUETTE 42-160 INFRARED EMISSIONS ANALYZER (LEFT SIDE)

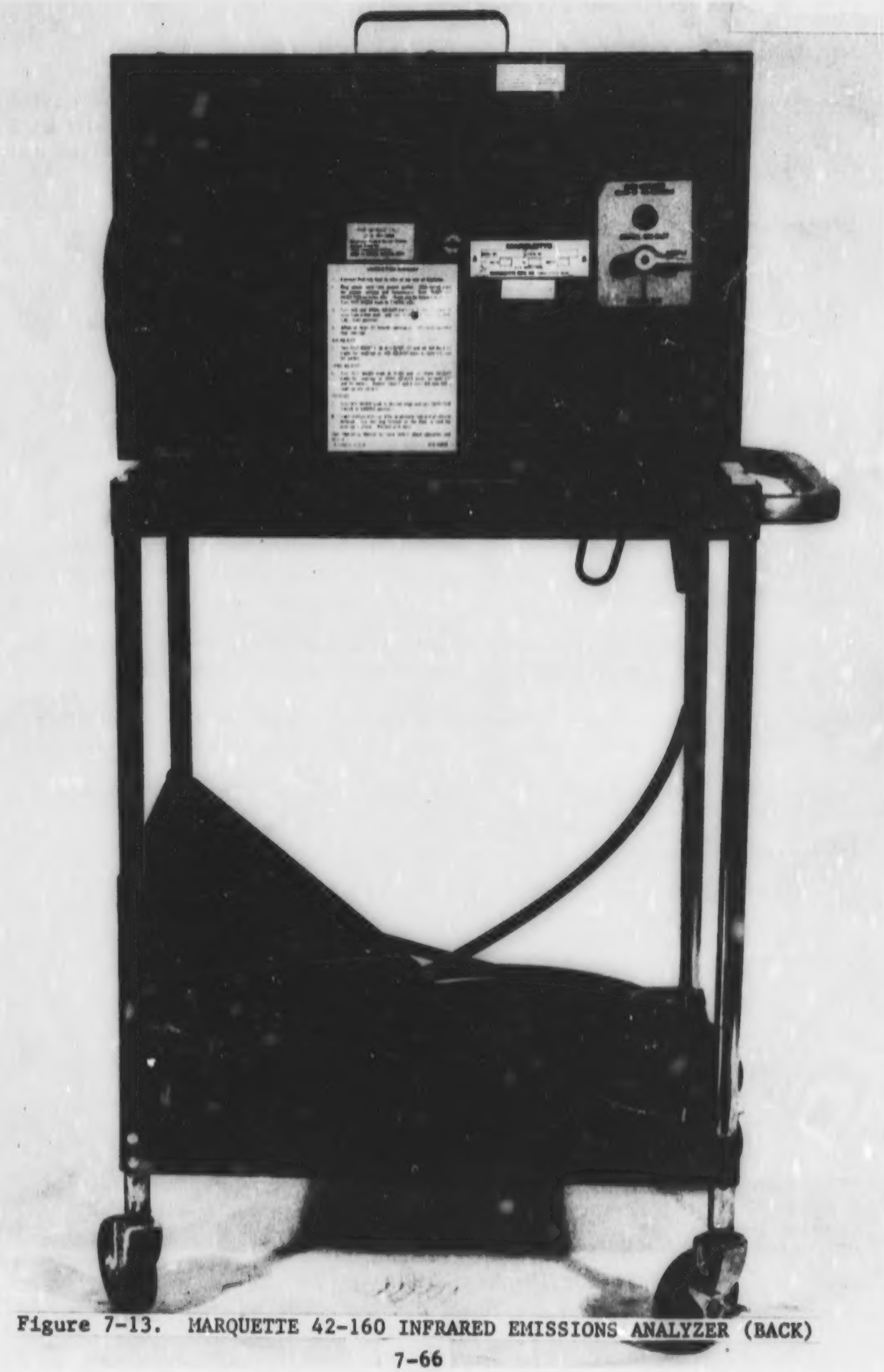

Figure 7-13. MARQUETTE 42-160 INFRARED EMISSIONS ANALYZER (BACK)

7.5 BECKMAN 590 HC/CO TESTER

Manufacturer - Beckman Instruments, Inc.

Description - HC/CO exhaust analyzer configured as a bench top analyzer secured to a four-wheeled cart. The analyzer could be used with or without the cart with equal ease. The cart incorporates two shelves for storage.

Dimensions -

Analyzer - Height - 10 inches
Width - 20 inches
Depth - 20 inches (with water trap)

Cart with Analyzer - Height - 45 inches
Width - 23 inches
Depth - 17 inches
Weight - Analyzer - 85 lbs. Cart - 45 lbs.

Analyzer is mounted on 30° angle on cart top.

Material of Construction - Analyzer cover - sheet aluminum. Analyzer front - brushed sheet metal. Cart shelves - steel tubing welded and screwed together.

Color - Analyzer - Orange with silver brushed steel front panel. Cart - Orange top shelf, black bottom shelf, chrome legs.

Mobility - Four, 5-inch, swiveling wheels. Front wheels incorporate mechanical locks. Mobility and stability are rated excellent.

Accessories - Sample probe, 25-foot sample hose, operator's manual.

Control Package -

Front Access - HC range and mode switch (three-position)
1. 2000 ppm
2. 400 ppm
3. Calibrate
HC zero - knob (with locking ring)
HC calibration - knob (with locking ring)
CO range and mode switch (three-position)
1. 10%
2. 2%
3. Calibrate
CO zero - know (with locking ring)
CO calibration (knob) (with locking ring)
Sample Mode Valve (two-position)
1. Container
2. Probe
On/Standby switch (toggle)
Flow Indicator (mechanical)

Side Access -
2% CO set - screw
CO cal - screw
400 ppm set - screw
HC cal - screw

Rear Access recorder jacks (TB)

Meters - 8", 90° swing
Black figures and scale graduations on white background.

Ranges - HC - 2000 ppm in 50 ppm increments
400 ppm in 10 ppm increments
CO - 10% in 0.2% increments
2% in 0.05% increments

Altitude scales on meter faces

Meters were not sensitive to static electricity (soft cloth rubbed over face of meter).

Altitude Compensation - Scales on meter faces used in conjunction with HC/CO cal pots (side access). Not needed with gas calibration at altitude of use.

Probe - Convoluted tubing with capped and perforated end, nonmetallic handle, tail pipe clamp.

Filters and Sample Handling - Water trap with 50 micron-sintered metal filter, dual head pump (water aspiration, sample transport), 25-foot sample hose, flow indicator.

Cal Gas Inlet - Unlabeled, on rear analyzer panel.

Power Requirements - 115 BAC 60/50HZ 275 watts

Operating Principles - Dual channel nondispersive infrared analyzer with optical filters, solid-state thermistor detector, hot wire sources, chopper wheel.

Calibration - Electronic reference signal using calibrate position of HC/CO mode switches. Altitude of test site set on meter faces. Gas calibration using rear panel port.

Operation and Calibration - Straightforward operation and sample system service directions are attached to the cart by a short chain. No gas calibration instructions are on analyzer or cart but are included in operator's manual.

Procedure -
1. Plug in and warm up (optical bench is powered up whenever instrument is plugged in)
2. Zero

3. Set altitude
4. Use
5. Optional gas calibration

7.5.1 Operational Performance Comments

Based upon the results of usage during these tests, this unit was judged to have the best overall cabinet and cart design. Mobility and stability during movement were excellent. This was attributed to the C.G. location, sturdy construction and utilization of large wheels. The cart is equipped with two large shelves that are used for power cord and sample hose storage. The tubular steel outer framework of the cart serves to protect the analyzer from damage. The only problem area for possible impact damage is the rear-mounted plastic water trap which protrudes approximately 3/4 inches past the rear steel tubes. The steel tubing also interferes with side access to the HC and CO calibration and set pots.

The fact that the rear calibration gas port was unlabeled caused slight confusion. The operator's manual does not identify this port.

One nice feature found on this instrument was the locking mechanism on the zero and calibration knobs. If properly used, these locks prevented accidental setting changes due to objects (hands) brushing against the knobs. The on/standby switch function should be described more completely in the operator's manual. It is not immediately clear that this instrument has no real off position unless the plug is pulled. The on/standby switch does not completely control all electrical functions in the unit. In the standby mode, certain components are powered up. In the on position, all components are powered up. During the warm up time tests, this unit was "switched on" by plugging in the cord with the switch in standby position.

The mechanical flow indicator appeared to be not quite sensitive enough for this application. This unit gave a progressive indication of flow degradation not available on those units equipped with flow indication lights. This progressive indication was easy to follow with good visibility due to the red/green color scheme and the front panel location of the indicator. Unfortunately, the performance of the unit would markedly degrade indicating flow blockage prior to flow restriction indicator operation. An increase in sensitivity would be worthwhile.

Operation of this unit reveals a moderately high level of noise and vibration due to the sample pump selection and mounting.

During various tests a random unpredictable drift pattern was observed. This interfered with some of the test readings. In the repeatability tests, cycles two, three and four, for zero drift showed the effects of this random drift phenomenon.

The print on the meters was relatively fine and might not be bold enough for use in less than optimum lighting conditions. The meters were not lighted on this unit. Additionally, no range indication lights were used. The range position switch was the only range indication and under certain lighting conditions, this switch position was hard to read.

In the laboratory tests, the unit demonstrated relatively long warm up times.

Zero drift in the laboratory and repeatability tests was large for the HC scale especially at high temperature. CO zero drift was 2 percent full scale or less under normal temperature and 3 percent full scale at high temperature. The only repeatable gas interference was 1 to 2 percent full scale CO response to CO_2.

In the accuracy determination tests, the Beckman was found to be third most accurate overall. During high altitude accuracy tests, the Beckman could not be adjusted for correct CO span while gas calibrating. High range gas was used and the CO "Calibration" pot was turned to its upper limit but the CO span gas value could not be reached.

The instrument showed fairly quick sampling response time and was relatively repetitive.

This unit was unresponsive to acetylene, benzene and ethylene. It was most responsive to isobutylene, followed by toluene and methane.

The Beckman 590 was essentially insenstive to voltage fluctuation.

The Beckman was fourth fest in overall EPA bench correlation during the vehicle tests.

This unit completed only 50 hours of testing in the durability sequence. This corresponds to 50,500 ppm-hours for HC and 102 percent-hours for CO. Failure resulted when both CO and HC meter readings went off scale (high end). The meters would not recover regardless of what corrective action was taken.

In the area of maintenance, during the durability tests, the 50 micron-sintered metal filter in the water trap repeatedly plugged requiring frequent attention. The sample hose and probe caused no problems.

Test data for Beckman 590 HC/CO Tester are shown in Tables 7-21 through 7-25.

Photographs of this instrument are shown in Figures 7-14, 7-15, and 7-16.

Attachment (1)

Table 7-21. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: BECKMAN 590

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	23	11	25	11
	LOW	CO	23	11	25	11

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	2.5	15.0	2.5	0.5
	LOW	CO	0	3.0	1.0	1.0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.5	-	0.5	0	0	0
	LOW	CO	1.0	0	-	0	0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 7.70	+ 2.7	- .54	- 0.2
	HIGH	HC/CO	70	+ 1.25	+ 0.55	+ 1.67	+ 1.0
	HIGH	HC/CO	100	- 0.58	- 0.55	- 0.61	- 0.6
	LOW	HC/CO	35	- 0.94	- 0.25	+ 1.45	+ 0.50
	LOW	HC/CO	70	- 2.4	- 1.50	+ 0.95	+ 0.50
	LOW	HC/CO	100	- 0.54	- 0.50	- 1.14	- 1.0
CYCLE 2	HIGH	HC/CO	35	+ 6.99	+ 2.45	- 3.23	- 1.2
	HIGH	HC/CO	70	- 3.87	- 1.3	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 1.54	- 1.4	+ 2.17	+ 2.0
	LOW	HC/CO	35	- 3.74	- 1.0	+ 7.25	+ 2.5
	LOW	HC/CO	70	- 2.01	- 1.25	0	0
	LOW	HC/CO	100	- 2.16	- 2.0	0	0

Table 7-21. DATA COMPOSITE - LABORATORY TEST (Cont'd)

BECKMAN 590

CYCLE 3	HIGH	HC/CO	35	+ 4.14	+ 1.45	- 0.54	- 0.20
	HIGH	HC/CO	70	+ 1.80	+ 1.30	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.71	- 0.65	0	0
	LOW	HC/CO	35	+ 2.80	+ 0.75	+ 8.70	+ 3.0
	LOW	HC/CO	70	- 3.62	- 2.25	+ 4.76	+ 2.5
	LOW	HC/CO	100	- 0.54	- 0.50	+ 1.71	+ 1.5
CYCLE 4	HIGH	HC/CO	35	+ 6.99	+ 2.45	+ 2.15	+ 0.80
	HIGH	HC/CO	70	- 2.49	- 1.8	+ 2.31	+ 1.50
	HIGH	HC/CO	100	- 1.26	- 1.15	+ 2.17	- 2.00
	LOW	HC/CO	35	- 2.80	+ 0.75	+ 8.70	+ 3.0
	LOW	HC/CO	70	- 2.81	- 1.75	+ 0.95	+ 0.5
	LOW	HC/CO	100	- .54	- 0.5	- 0.57	- 0.8
HIGH ALTITUDE	HIGH	HC/CO	35	+ 0.14	+ 0.05	INSTRUMENT	MALFUNCTION
	HIGH	HC/CO	70	- 3.18	- 2.30	"	"
	LOW	HC/CO	100	- 0.71	- 0.65	"	"
	LOW	HC/CO	35	+ 0.94	+ 0.25	"	"
	LOW	HC/CO	70	- 3.62	- 2.25	"	"
	LOW	HC/CO	100	- 0.27	- 0.25	"	"

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1749	9.7	7.0	11.25	15.0
	HIGH	CO	8.1	10.0	8.15	12.45	14.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	0	65	8	9
6750 Feet Altitude	LOW	0	0	5	75	8	22

Table 7-21. DATA COMPOSITE - LABORATORY TEST (Cont'd)

BECKMAN 590

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0	0
	115V	HIGH	CO	0	0.2

Table 7-22. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **BECKMAN 590**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	8	18	30	19
	LOW	CO	7	18	25	13

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	2.0	6.75	5.0	8.0
	LOW	CO	1.0	2.0	1.5	1.0

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.0	-	0.0	0.0	0.0	0.0
	LOW	CO	1.0	1.0	-	0.5	0.0	0.5

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	3.75	-	5.25	2.0	0	2.0
	LOW	CO	2.0	1.5	-	1.0	0.5	0.75

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	1	0	3.0	0
	LOW	CO	1.0	0	-	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	2.25	-	0	2.0	0	0
	LOW	CO	1.5	1.0	0	1.0	0	0.5

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1749	16	12.5	8.5	5
	HIGH	CO	8.1	16	12.5	11	7

Table 7-22. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

BECKMAN 590

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+6.99	+2.45	-1.88	-0.70
	HIGH	HC/CO	70	-8.71	-6.30	+4.62	+3.00
	HIGH	HC/CO	100	-1.26	-1.15	+1.63	+1.50
	LOW	HC/CO	35	+7.48	+2.00	+8.70	+3.00
	LOW	HC/CO	70	+2.41	+1.50	+0.95	+0.50
	LOW	HC/CO	100	+2.43	+2.25	+1.14	+1.00
CYCLE 2	HIGH	HC/CO	35	+8.42	+2.95	-0.54	-0.20
	HIGH	HC/CO	70	-1.80	-1.30	+3.08	+2.0
	HIGH	HC/CO	100	+0.11	+0.10	+1.09	+1.0
	LOW	HC/CO	35	-6.54	-1.75	+10.14	+3.50
	LOW	HC/CO	70	+0.40	+0.25	-0.95	-0.50
	LOW	HC/CO	100	-0.27	-0.25	-0.57	-0.50
CYCLE 3	HIGH	HC/CO	35	+16.98	+5.95	-1.88	-0.70
	HIGH	HC/CO	70	+2.35	+1.70	-0.77	-0.50
	HIGH	HC/CO	100	+3.68	+3.35	0	0
	LOW	HC/CO	35	0	0	+7.25	+2.5
	LOW	HC/CO	70	-3.61	-2.25	0	0
	LOW	HC/CO	100	+3.23	+3.00	+0.57	+0.50
CYCLE 4	HIGH	HC/CO	35	+7.28	+2.55	-3.23	-1.20
	HIGH	HC/CO	70	-1.11	-0.80	+1.69	+1.10
	HIGH	HC/CO	100	+0.05	+0.05	-1.30	-1.20
	LOW	HC/CO	35	+0.93	+0.25	+13.04	+4.50
	LOW	HC/CO	70	+4.02	+2.50	+0.95	+0.50
	LOW	HC/CO	100	+0.54	+0.50	+2.29	+2.0

Table 7-23. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

BECKMAN 590

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	400/2	HC/CO	50	- 21.84	- 5.45	+ 2.74	+ 0.01
	400/2	HC/CO	30	- 14.72	- 4.1	- 7.14	- 0.5
	400/2	HC/CO	IDLE	- 2.84	- 1.5	+ 16.33	+ 0.12
CYCLE 2	400/2	HC/CO	50	- 10.99	- 2.63	+ 23.08	+ 0.75
	400/2	HC/CO	30	- 15.3	- 4.43	- 6.25	- 0.5
	400/2	HC/CO	IDLE	- 19.87	- 12.4	+ 26.21	+ 13.5
CYCLE 3	400/2	HC/CO	50	- 9.95	- 2.63	+ 16.44	+ 6.0
	400/2	HC/CO	30	+ 3.75	+ 0.95	+ 7.14	+ 0.5
	400/2	HC/CO	IDLE	+ 9.09	+ 4.38	+ 26.87	+ 18.0
CYCLE 4	400/2	HC/CO	50	- 26.07	- 6.88	+ 34.33	+ 11.5
	400/2	HC/CO	30	- 11.74	- 3.23	+ 36.36	+ 2.0
	400/2	HC/CO	IDLE	+ 27.5	+ 10.3	+ 13.64	+ 9.0
LEAN MODE CYCLE 1	400/2	HC/CO	50	- 33.88	- 8.33	- 5.48	- 2.0
	400/2	HC/CO	30	- 29.82	- 7.23	- 14.29	- 1.0
	2000/2	HC/CO	IDLE	+ 39.88	+ 14.26	0	0
CYCLE 2	400/2	HC/CO	50	- 28.08	- 0.65	+ 17.74	+ 5.5
	400/2	HC/CO	30	+ 5.21	+ 1.3	~~+ 60.0~~	~~+ 3.0~~
	2000/2	HC/CO	IDLE	+ 48.7	+ 10.24	+ 37.93	+ 5.5
CYCLE 3	400/2	HC/CO	50	+ 4.27	+ 1.13	+ 7.14	+ 3.0
	400/2	HC/CO	30	+ 3.32	+ 0.88	+ 60.0	+ 3.0
	400/2	HC/CO	IDLE	- 17.48	- 17.48	+ 42.86	+ 9.0
CYCLE 4	400/2	HC/CO	50	- 14.21	- 3.85	+ 6.67	+ 2.5
	400/2	HC/CO	30	- 18.11	- 4.98	+ 8.33	+ 0.5
	2000/2	HC/CO	IDLE	- 1.34	- 0.31	+ 29.63	+ 4.0

Table 7-23. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

BECKMAN 590

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	400/2	HC/CO	50	+ 17.02	+ 4.0	+ 29.03	+ 9.0
	400/2	HC/CO	30	+ 13.74	+ 3.63	+ 50.0	+ 3.0
	400/10	HC/CO	IDLE	+ 10.72	+ 6.9	+ 19.12	+ 6.1
CYCLE 2	400/2	HC/CO	50	+ 10.92	+ 3.2	+ 14.52	+ 4.5
	400/2	HC/CO	30	+ 27.96	+ 7.38	+ 25.0	+ 1.5
	400/10	HC/CO	IDLE	+ 6.94	+ 4.95	+ 11.11	+ 4.1
CYCLE 3	400/2	HC/CO	50	+ 17.02	+ 4.0	+ 29.03	+ 9.0
	400/2	HC/CO	30	+ 13.74	+ 3.63	+ 50.0	+ 3.0
	400/10	HC/CO	IDLE	+ 10.72	+ 6.9	+ 19.12	+ 6.1
CYCLE 4	400/2	HC/CO	50	- 6.28	- 1.73	- 2.94	- 1.0
	400/2	HC/CO	30	+ 4.27	+ 1.13	+ 7.69	+ 0.5
	400/10	HC/CO	IDLE	- 17.58	- 13.28	+ 1.60	+ 0.6

Table 7-24. DIAGNOSTIC TEST

BECKMAN 590

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1340	1120	+ 19.64	+ 11.0
	10%	CO	2.90	2.15	+ 34.88	+ 7.5
NORMAL IDLE	2000	HC	400	458.4	- 12.74	- 292
	10%	CO	2.90	2.06	+ 40.78	+ 8.4
IGNITION ADVANCE	2000	HC	400	365.9	+ 9.32	+ 1.71
	10%	CO	2.90	2.14	+ 35.51	+ 7.6
IGNITION RETARD	2000	HC	625	490.5	+ 27.42	+ 6.73
	10%	CO	3.18	2.40	+ 32.5	+ 7.8

Table 7-25. DURABILITY TEST DATA

INSTRUMENT: BECKMAN 590

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	50
HC EXPOSURE (PPM-HRS.)	50,500
CO EXPOSURE (%-HRS.)	102
NO EXPOSURE (PPM-HRS.)	5,200
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	0
SHOCK TEST FAILURE RATE (Failure/Day %)	0
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	0
HC SPAN	0
CO ZERO	0
CO SPAN	0
AVERAGE DAILY SPAN DRIFT	
HC%	0.89
CO%	0.63
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	3
PER 100 HRS.	6
B DRAIN HOSE	
TOTAL	2
PER 100 HRS.	4
C REZERO	
TOTAL	--
PER 100 HRS.	--
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	--
PER 100 HRS.	--

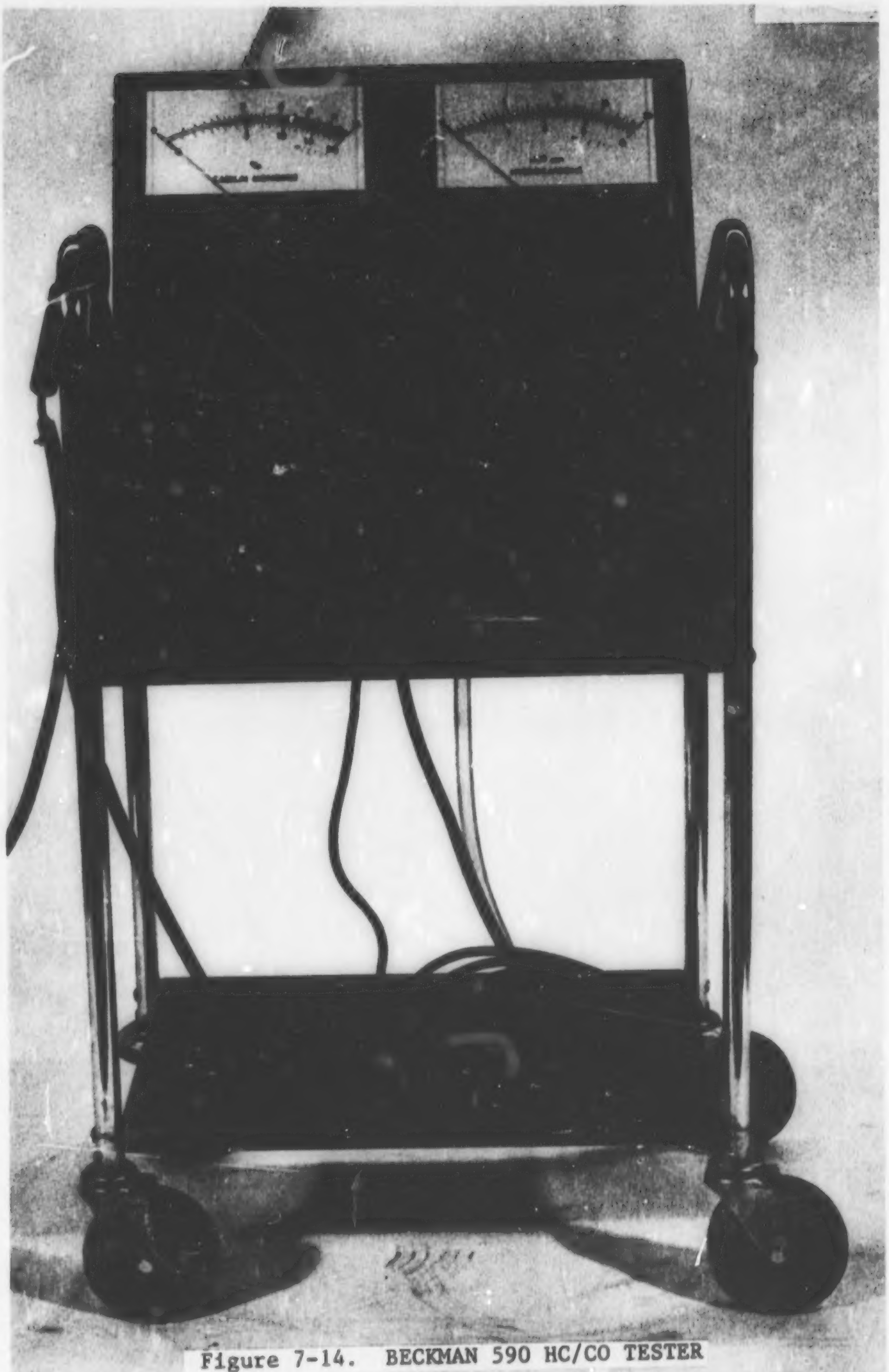

Figure 7-14. BECKMAN 590 HC/CO TESTER

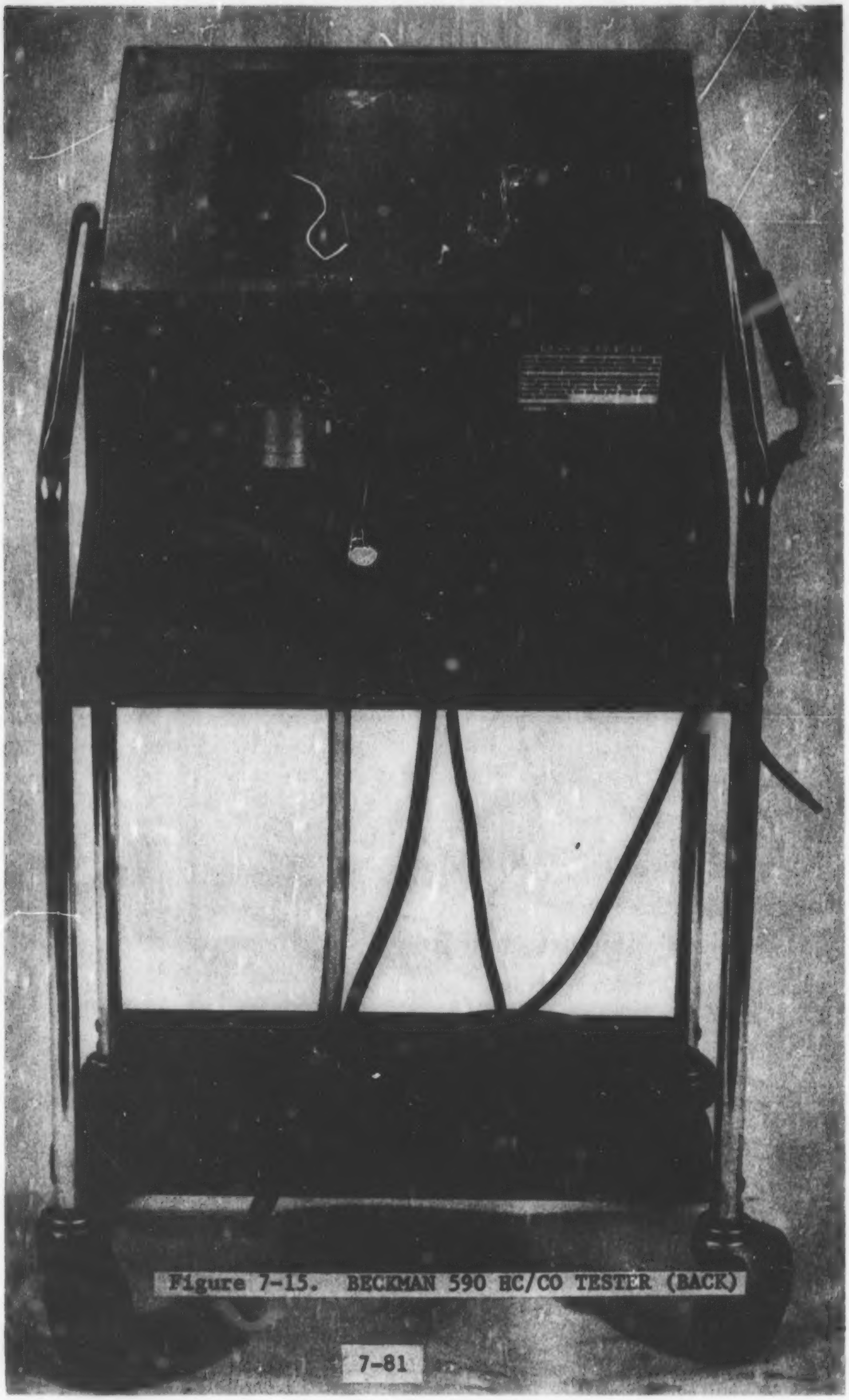

Figure 7-15. BECKMAN 590 HC/CO TESTER (BACK)

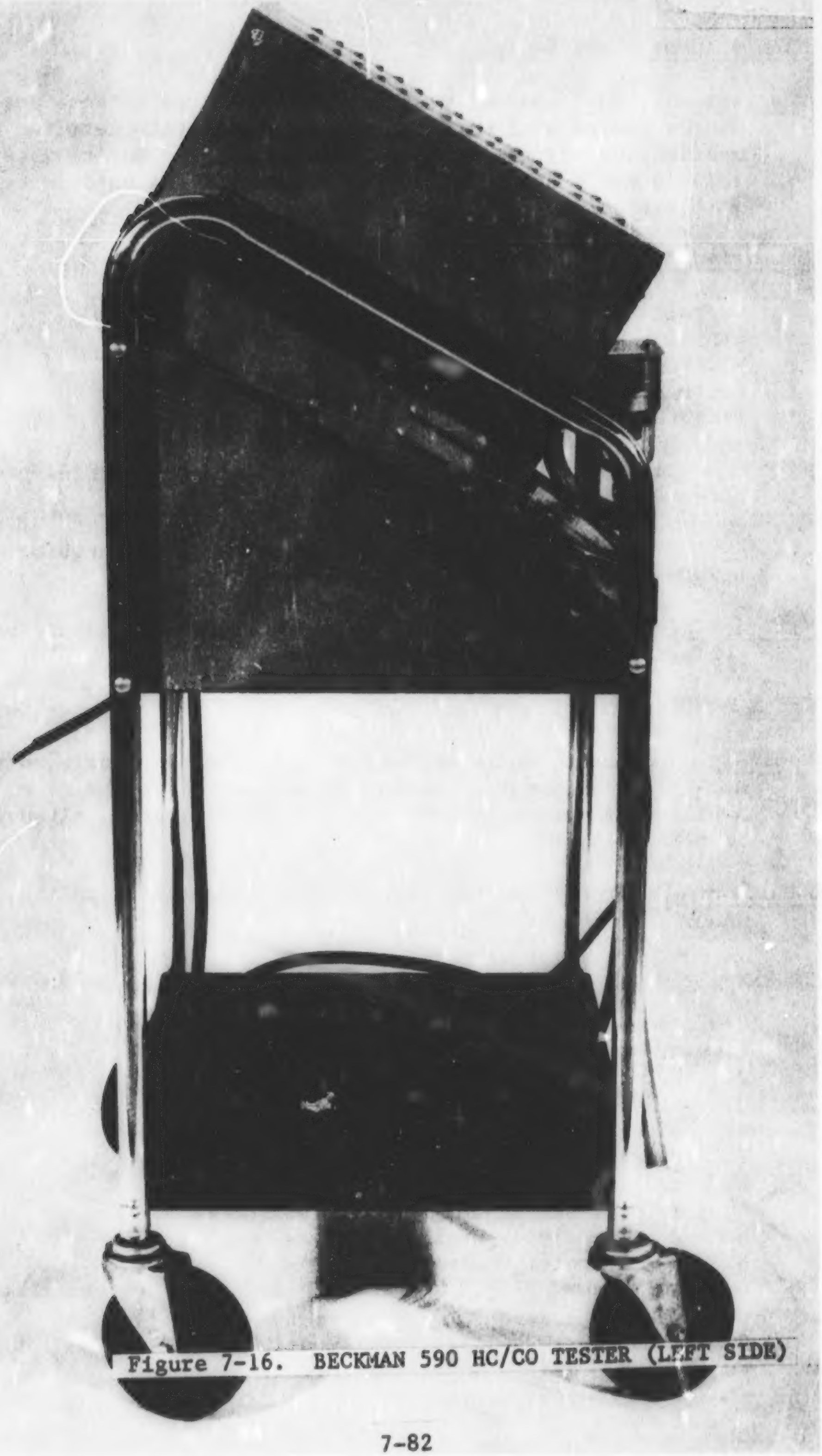

Figure 7-16. BECKMAN 590 HC/CO TESTER (LEFT SIDE)

7.6 STEWART WARNER 3161 INFRARED GAS ANALYZER

Manufacturer - Kal Equip

Description - Dual chamber nondispersive infrared exhaust analyzer. Single source with mirrors, single solid-state detector with mirrors multiplying circuit keyed to chopper wheel. Rotating optical filters. This is not a bench top unit. It can only be used in conjunction with its cart.

Dimensions -

Overall
Height - 43-1/4 inches
Width - 22-5/8 inches
Depth - 18-1/2 inches
Weight - 58 lbs.

Cart has no storage areas. Rear of cabinet equipped with hanger for power cord.

Overall package is best described as a rectangular analyzer box, mounted on a sheet-metal pedestal.

Material of Construction - Sheet-metal cabinet with plastic back panel. Cabinet is welded and screwed together.

Color - White with brown face and brown base.

Mobility - Two rear, nonswiveling, 8-inch diameter wheels, with two sheet metal legs in front. The handle is mounted on the rear of the unit. Mobility is generally good with the large wheels, although the C.G. is relatively high.

Accessories - Probe, 12-foot sample hose, calibration pot tools, operator's manual.

Control Package -

Front Access - Function selector (five-position)
1. Off
2. Zero
3. Set mark
4. Hi scale
5. Lo scale

HC zero - knob
HC - 1 (set mark adjust) - Hexagonal screw
HC - 2 (Hi scale) - Hexagonal screw
HC - 3 (Lo scale) - Hexagonal screw
CO zero - knob
CO calibrate - knob
CO - 1 (set mark adjust) - Hexagonal screw
CO - 2 (Hi scale) - Hexagonal screw

CO - 3 (Lo scale) - Hexagonal screw
Change filter - indicator light
Range indicator lights - on meter faces

Rear Panel - Calibration valve (two-position)
1. Internal
2. External

Span gas inlet port.

Meters - 8-1/2", 90° swing

Figures and division - black on white background

Ranges - HC - 2000 ppm in 50 ppm increments
500 ppm in 10 ppm increments
CO - 10% in 0.2% increments
2.5% in 0.1% increments

These meters were not sensitive to static electricity (soft cloth rubbed across meter lens).

Altitude Compensation - Set mark on meter face used in conjunction with chart in operator's manual. Not needed if gas calibration is performed at test site.

Probe - Steel tubing with flexible tip. A filter screen is located in the flexible tip end to remove large particles. A wooden handle is used on the probe and a spring assembly holds the probe in the tail pipe.

Filters and Sample Handling - This unit incorporates a primary particulate screen in the probe tip, a secondary particulate filter in the probe handle, a water trap (air dryer), and an air-cooled water separator assembly for further moisture collection.

Cal Gas Inlet - On rear of instrument

Power Requirements - 11-15.7 VDC 8.5 amps

Operating Principles - Single-cell, rotating optical filters, chopper modulates infrared energy and synchronizing windows in chopper wheel picks appropriate HC and CO circuit.

Calibration - Basically straightforward except that Lo and Hi scales have their own span adjustments resulting in four "span" related pots for each circuit. With function selector and span pots, this unit is more complicated to calibrate than some other units.

Operation and Calibration - Operating instructions are printed on the front of the instrument. Calibration procedures are on back panel.

Operations -

1. Place "function selector" in zero position
2. Warm up
3. Zero
4. Calibrate adjust to set marks
5. Ready for use
6. Optional gas calibration

7.6.1 Operational Performance Comments

The unit utilized range identification lights which were found to be very helpful during instrument use.

The unit incorporated a "change filter" indicator light on the front panel. The indicator worked very well during all tests.

The lack of a sample hose hanger on this unit was very inconvenient. In addition, the sample hose was extremely stiff and relatively hard to manipulate. The 12-foot length of the hose was considered too short for general use, especially when the hose stiffness was taken into account.

The gas calibration port and gas selection valve, located on the rear panel, were inconvenient. The hexagonal span pot tool was hard to use during calibration and the blind holes in the cabinet face made span pot adjustment difficult. The selector valve was easy to set incorrectly without detection.

This unit operated on 12 VDC power and was subject to the limitation of frequent on/off cycling by the user, resulting in insufficient warm up and poor stability, accuracy and repeatability. It is recognized that the use of 12 VDC power may circumvent problems related to electrical testing laboratory approval and various agency acceptance criteria.

There was no over-voltage protection built into the instrument, thus a malfunctioning charging system in an automobile could damage components in the instrument even though the manufacturer rates the instrument for operation on DC voltages between 11 VDC and 15.7 VDC.

The sample handling system presented some problems in the area of maintenance. A heat sink cooling tube was located on the interior of the analyzer housing and was difficult to remove during servicing. The secondary particulate filter could only serviced by disassembling the sample probe handle. Repeated changing of this fiber cartridge filter caused the connections in the probe housing to loosen. Located at the bottom of the pedestal stand was a small water trap with a downward pointed outlet. This water trap presented no problems during tests.

In the laboratory tests, this unit showed relatively short warm up times; on the order of 8 to 10 minutes. At low temperatures, the warm up time increased two-fold. Zero drift performance was very good at all temperatures, never exceeding 1.2 percent full scale. The effects of interference gases were minimal. Slight interscale sensitivity was noted but the effects did not exceed 1.6 percent full scale. NO interference caused 1.2 percent full scale fluctuation in the CO meter.

In span gas accuracy, the Stewart Warner was twelfth most accurate with the most apparent problem seen in the low CO scale. High altitude accuracy was not significantly different than low altitude tests.

Response test performance indicated relatively slow times although relatively consistent.

This unit was not responsive to acetylene or benzene. It was most responsive to isobutylene, followed by methane, toluene and ethylene.

Voltage fluctuation caused slight HC meter response but caused 1.0 percent full scale CO meter response for both plus and minus 10 percent voltage variations.

This unit experienced an electronic failure during repeatability tests. The unit was returned to the local service facility where repairs were made. Diagnosis discovered intermittent circuits on a circuit board and a number of bad I.C's. After repair, the instrument was returned for further tests but all repeatability tests were missed.

In the vehicle test sequence, the Stewart Warner correlated twelfth best with the EPA instrument.

The unit demonstrated very poor exhaust correlation during the vehicle test. Instrument failure occurred three times during the vehicle tests. Each failure occurred in the fourth cycle of each loaded steady-state mode. At the beginning of each fourth cycle, both meters gave full scale needle indications and could not be returned to zero. There was no water visible in the water trap or clear tubing in the system. The "change filter" light did not illuminate.

On the front panel of this instrument there is a sticker which states the following: "Caution use of this instrument on an engine which is not at operating temperature may cause moisture to deposit internally. If this occurs both meter pointers may go to full scale and stay there. This condition can be corrected by operating unit for ten (10) minutes or more with function selector switch in zero position." After each of the three cycle failures, the instrument was run for an extended period of time in the zero position. The unit recovered satisfactorily each time. It must be concluded that internal water accumulation was the problem. It is noted that during interference gas tests, this instrument did not indicate sensitivity to water vapor.

It is possible that the poor exhaust correlation performance is at least partly attributable to water vapor interference. Apparently, this specific sampling system cannot handle the moisture level encountered in prolonged loaded steady-state tests.

During the durability test, the sample probe broke at the junction between the flexible spiral tubing and the hard tube extension. This unit completed 276 hours of durability testing. This corresponds to 227,424 ppm-hours of HC exposure and 218 percent-hours of CO exposure. Failure occurred when both meters gave high zero readings that would not respond to zeroing attempts. A zero position dry-out mode of operation brought the meters back to near normal operation. The next day during calibration, the HC scale could not be zeroed and would not respond to a zero position dry-out mode.

Upon internal observation, it was noted the optical bench and sample system used on this unit is almost identical with that used on the Kal Equip 4094D. The most obvious difference between the two units is in packaging; the Stewart Warner housed in a mobile sheet metal enclosure, and the Kal Equip configured as a molded plastic encased portable unit. There are other slight physical and operational differences between the two units but, in general, comparison of the two units can be considered as a package variation of the same basic bench. It is interesting to note that although the Kal Equip is not supplied with a bowl-type water trap, using only the air-cooled tube, it never experienced total failure attributable to internal water accumulation.

The Kal Equip did show the same pattern of poor exhaust correlation during the vehicle tests as seen in the Stewart Warner.

Test data for Stewart Warner 3161 Infrared Gas Analyzer are shown in Tables 7-26 through 7-30.

Photographs of this instrument are shown in Figures 7-17, 7-18 and 7-19.

Table 7-26. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: STEWART WARNER 3161

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	8	10	21	9
	LOW	CO	8	10	21	9

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	1.0	1.0	1.2	0.6
	LOW	CO	1.2	0.8	0.4	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	1.0	0	0	0
	LOW	CO	0.4	1.6	-	0	1.2	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC % ERROR ABSOLUTE	HC % ERROR FS	CO % ERROR ABSOLUTE	CO % ERROR FS
CYCLE 1	HIGH	HC/CO	35	- 4.07	- 1.40	+ 2.15	+ 0.80
	HIGH	HC/CO	70	- 4.80	- 3.40	- 1.54	- 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	- 2.17	- 2.00
	LOW	HC/CO	35	- 1.13	- 0.40	+ 0.95	+ 0.40
	LOW	HC/CO	70	+ 4.40	+ 3.20	- 2.29	- 1.60
	LOW	HC/CO	100	+ 0.40	+ 0.40	0	0
CYCLE 2	HIGH	HC/CO	35	- 6.25	- 2.15	+ 1.88	+ 0.70
	HIGH	HC/CO	70	- 1.62	- 1.15	+ 1.54	+ 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	+ 3.26	+ 3.00
	LOW	HC/CO	35	- 9.61	- 3.40	- 4.76	- 2.00
	LOW	HC/CO	70	+ 1.65	+ 1.20	- 1.14	- 0.80
	LOW	HC/CO	100	+ 2.20	+ 2.20	- 6.82	- 6.00

Table 7-26. DATA COMPOSITE - LABORATORY TEST (Cont'd)

STEWART WARNER 3161

CYCLE 3	HIGH	HC/CO	35	- 5.52	- 1.90	+ 2.15	+ 0.80
	HIGH	HC/CO	70	- 4.80	- 3.40	- 1.54	- 1.00
	HIGH	HC/CO	100	+ 0.06	+ 0.05	- 3.26	- 3.00
	LOW	HC/CO	35	- 4.52	- 1.60	+ 3.81	+ 1.60
	LOW	HC/CO	70	+ 4.12	+ 3.00	+ 2.86	+ 2.00
	LOW	HC/CO	100	+ 1.20	+ 1.20	- 4.55	- 4.00
CYCLE 4	HIGH	HC/CO	35	- 5.52	- 1.9	+ 2.15	+ 0.80
	HIGH	HC/CO	70	- 4.09	- 2.9	- 1.54	- 1.00
	HIGH	HC/CO	100	+ 0.62	+ 0.55	- 3.26	- 3.0
	LOW	HC/CO	35	- 3.96	- 1.4	- 4.76	- 2.00
	LOW	HC/CO	70	+ 4.12	+ 2.8	- 8.57	- 6.00
	LOW	HC/CO	100	+ 2.20	+ 2.2	-18.18	-16.00
HIGH ALTITUDE	HIGH	HC/CO	35	- 6.98	- 2.4	- 0.54	- 0.20
	HIGH	HC/CO	70	- 5.50	- 3.9	- 3.08	- 2.00
	HIGH	HC/CO	100	0	0	+ 1.09	+ 1.00
	LOW	HC/CO	35	- 2.26	- 0.40	+ 1.91	+ 0.80
	LOW	HC/CO	70	+ 1.92	+ 1.40	- 1.71	- 1.20
	LOW	HC/CO	100	+ 2.20	+ 2.2	- 6.82	- 6.00

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1716	28.5	37.0	35.5	43.5
	HIGH	CO	8.1	32.5	36.5	36.5	41.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	5	55	10	5
6750 Feet Altitude	LOW	5	0	5	60	10	12

Table 7-26. DATA COMPOSITE - LABORATORY TEST (Cont'd)

STEWART WARNER 3161

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	13.6V	HIGH	HC	0.80	0.45
	13.6V	HIGH	CO	1.00	1.00

Table 7-27. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: STEWART WARNER 3161

<table>
<tr><td rowspan="3">WARMUP TIME (Min.)</td><td>RANGE</td><td>SCALE</td><td>(CYCLE 1)</td><td>(CYCLE 2)</td><td colspan="2">(CYCLE 3)</td><td colspan="2">(CYCLE 4)</td></tr>
<tr><td></td><td></td><td colspan="4">INSTRUMENT MALFUNCTION</td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="4">ZERO DRIFT</td><td rowspan="2">RANGE</td><td rowspan="2">SCALE</td><td colspan="6">MAXIMUM ZERO DRIFT % FULL SCALE</td></tr>
<tr><td>(CYCLE 1)</td><td>(CYCLE 2)</td><td colspan="2">(CYCLE 3)</td><td colspan="2">(CYCLE 4)</td></tr>
<tr><td></td><td></td><td colspan="4">INSTRUMENT MALFUNCTION</td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="3">GAS INTERFERENCE (% of FS)
CYCLE 1</td><td>RANGE</td><td>SCALE</td><td>15% CO_2/N_2</td><td>1600ppm HC/N_2</td><td>10% CO/N_2</td><td>3% H_2O/AIR</td><td>2000ppm NO/N_2</td><td>10% O_2/N_2</td></tr>
<tr><td></td><td></td><td colspan="3">INSTRUMENT MALFUNCTION</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">GAS INTERFERENCE (% of FS)
CYCLE 2</td><td>RANGE</td><td>SCALE</td><td>15% CO_2/N_2</td><td>1600ppm HC/N_2</td><td>10% CO/N_2</td><td>3% H_2O/AIR</td><td>2000ppm NO/N_2</td><td>10% O_2/N_2</td></tr>
<tr><td></td><td></td><td colspan="3">INSTRUMENT MALFUNCTION</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">GAS INTERFERENCE (% of FS)
CYCLE 3</td><td>RANGE</td><td>SCALE</td><td>15% CO_2/N_2</td><td>1600ppm HC/N_2</td><td>10% CO/N_2</td><td>3% H_2O/AIR</td><td>2000ppm NO/N_2</td><td>10% O_2/N_2</td></tr>
<tr><td></td><td></td><td colspan="3">INSTRUMENT MALFUNCTION</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">GAS INTERFERENCE (% of FS)
CYCLE 4</td><td>RANGE</td><td>SCALE</td><td>15% CO_2/N_2</td><td>1600ppm HC/N_2</td><td>10% CO/N_2</td><td>3% H_2O/AIR</td><td>2000ppm NO/N_2</td><td>10% O_2/N_2</td></tr>
<tr><td></td><td></td><td colspan="3">INSTRUMENT MALFUNCTION</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">RESPONSE & RECOVERY</td><td rowspan="2">RANGE</td><td rowspan="2">SCALE</td><td rowspan="2">CORRECTED CONCENTRATION</td><td colspan="5">INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)</td></tr>
<tr><td>(CYCLE 1)</td><td>(CYCLE 2)</td><td>(CYCLE 3)</td><td colspan="2">(CYCLE 4)</td></tr>
<tr><td></td><td></td><td colspan="3">INSTRUMENT MALFUNCTION</td><td></td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

STEWART WARNER 3161

Table 7-27. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1			INSTRUMENT	MALFUNCTION			
CYCLE 2			INSTRUMENT	MALFUNCTION			
CYCLE 3			INSTRUMENT	MALFUNCTION			
CYCLE 4			INSTRUMENT	MALFUNCTION			

Table 7-28. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

STEWART WARNER 3161

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	2000/10	HC/CO	50	- 47.16	- 14.28	+ 69.01	+ 19.6
	2000/10	HC/CO	30	- 52.35	- 15.38	+ 81.82	+ 3.6
	2000/10	HC/CO	IDLE	- 18.49	- 11.34	+ 61.76	+ 16.8
CYCLE 2	2000/10	HC/CO	50	- 38.36	- 11.58	+ 61.29	+ 15.2
	2000/10	HC/CO	30	- 40.7	- 12.08	+166.67	+ 8.0
	2000/10	HC/CO	IDLE	- 39.65	- 21.02	+ 58.16	+ 22.8
CYCLE 3	2000/10	HC/CO	50	- 60.44	- 15.28	+118.75	+ 22.8
	2000/10	HC/CO	30	- 57.59	- 14.94	+100.0	+ 5.2
	2000/10	HC/CO	IDLE	- 47.99	- 25.84	+ 20.97	+ 10.4
CYCLE 4	2000/10	HC/CO	50		FAILED		
	2000/10	HC/CO	30		FAILED		
	2000/10	HC/CO	IDLE		FAILED		
LEAN MODE CYCLE 1	500/2.5	HC/CO	50	- 44.16	- 12.18	+ 42.86	+ 10.8
	500/2.5	HC/CO	30	- 49.97	- 14.98	+ 50.0	+ 2.4
	500/2.5	HC/CO	IDLE	- 38.64	- 25.82	+ 45.45	+ 10.0
CYCLE 2	500/2.5	HC/CO	50	- 40.31	- 11.48	+ 52.54	+ 12.4
	500/2.5	HC/CO	30	45.33	- 13.6	+127.27	+ 5.6
	500/2.5	HC/CO	IDLE	- 41.63	- 29.96	+ 60.0	+ 12.0
CYCLE 3	500/2.5	HC/CO	50	- 48.58	- 12.28	+ 35.87	+ 13.2
	500/2.5	HC/CO	30	- 49.26	- 12.62	+100.0	+ 5.6
	500/2.5	HC/CO	IDLE	+ 21.33	+ 4.5	+ 12.9	+ 3.2
CYCLE 4	500/2	HC/CO	50		FAILED		
	500/2.5	HC/CO	30		FAILED		
	500/2.5	HC/CO	IDLE		FAILED		

Table 7-28. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

STEWART WARNER 3161

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	500/2.5	HC/CO	50	- 40.59	- 12.16	+ 53.85	+ 14.0
	500/2.5	HC/CO	30	+ 40.0	- 12.0	+ 45.45	+ 4.0
	500/10	HC/CO	IDLE	- 32.45	- 26.9	+ 27.64	+ 9.7
CYCLE 2	500/2.5	HC/CO	50	- 33.65	- 8.62	+ 50.0	+ 16.0
	500/2.5	HC/CO	30	- 42.88	- 11.26	+100.0	+ 5.6
	500/10	HC/CO	IDLE	- 29.03	- 18.82	+ 16.62	+ 5.7
CYCLE 3	400/2.5	HC/CO	50	- 33.65	- 8.62	+ 73.91	+ 20.4
	400/2.5	HC/CO	30	- 35.18	- 8.9	+150.0	+ 8.4
	400/10	HC/CO	IDLE	- 11.59	- 6.82	+ 35.65	+ 11.3
CYCLE 4		HC/CO	50		FAILED		
		HC/CO	30		FAILED		
		HC/CO	IDLE		FAILED		

Table 7-29. DIAGNOSTIC TEST

STEWART WARNER 3161

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1300	1550	- 16.13	- 12.5
	10%	CO	3.5	2.95	+ 18.64	+ 5.5
NORMAL IDLE	2000	HC	650	713	- 8.84	- 3.15
	10%	CO	3.50	3.05	+ 14.75	+ 4.5
IGNITION ADVANCE	2000	HC	550	680	- 9.12	- 6.5
	10%	CO	3.70	3.11	+ 18.97	+ 5.9
IGNITION RETARD	2000	HC	550	706	- 22.10	- 7.8
	10%	CO	3.80	3.09	+ 22.98	+ 7.1

Table 7-30. DURABILITY TEST DATA

INSTRUMENT: STEWART WARNER 3161

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	276
HC EXPOSURE (PPM-HRS.)	227,424
CO EXPOSURE (%-HRS.)	218
NO EXPOSURE (PPM-HRS.)	26,772
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	5
SHOCK TEST FAILURE RATE (Failure/Day %)	27.78
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	0
HC SPAN	1
CO ZERO	0
CO SPAN	4
AVERAGE DAILY SPAN DRIFT	
HC%	6.65
CO%	11.44
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER TOTAL PER 100 HRS.	 6 2.17
B DRAIN HOSE TOTAL PER 100 HRS.	 1 0.36
C REZERO TOTAL PER 100 HRS.	 1 0.36
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	 4 1.45
E. OTHER TOTAL PER 100 HRS.	 2 0.72

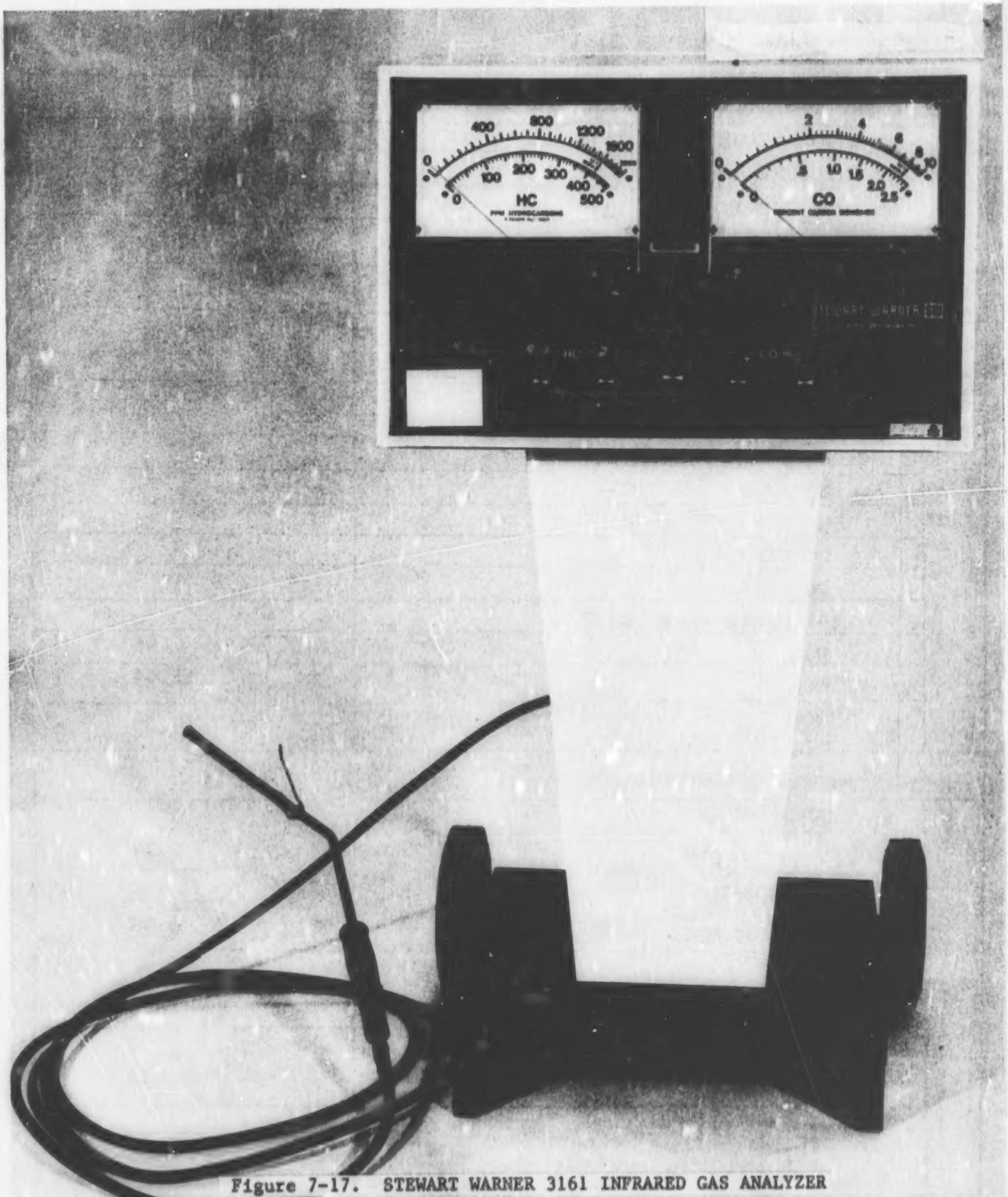
0
400
800
1200
1600
100
200
300
400
500
HC
PPM HYDROCARBONS
0
2
4
6
8
10
.5
1.0
1.5
2.0
2.5
CO
PERCENT CARBON MONOXIDE
STEWART WARNER

Figure 7-17. STEWART WARNER 3161 INFRARED GAS ANALYZER

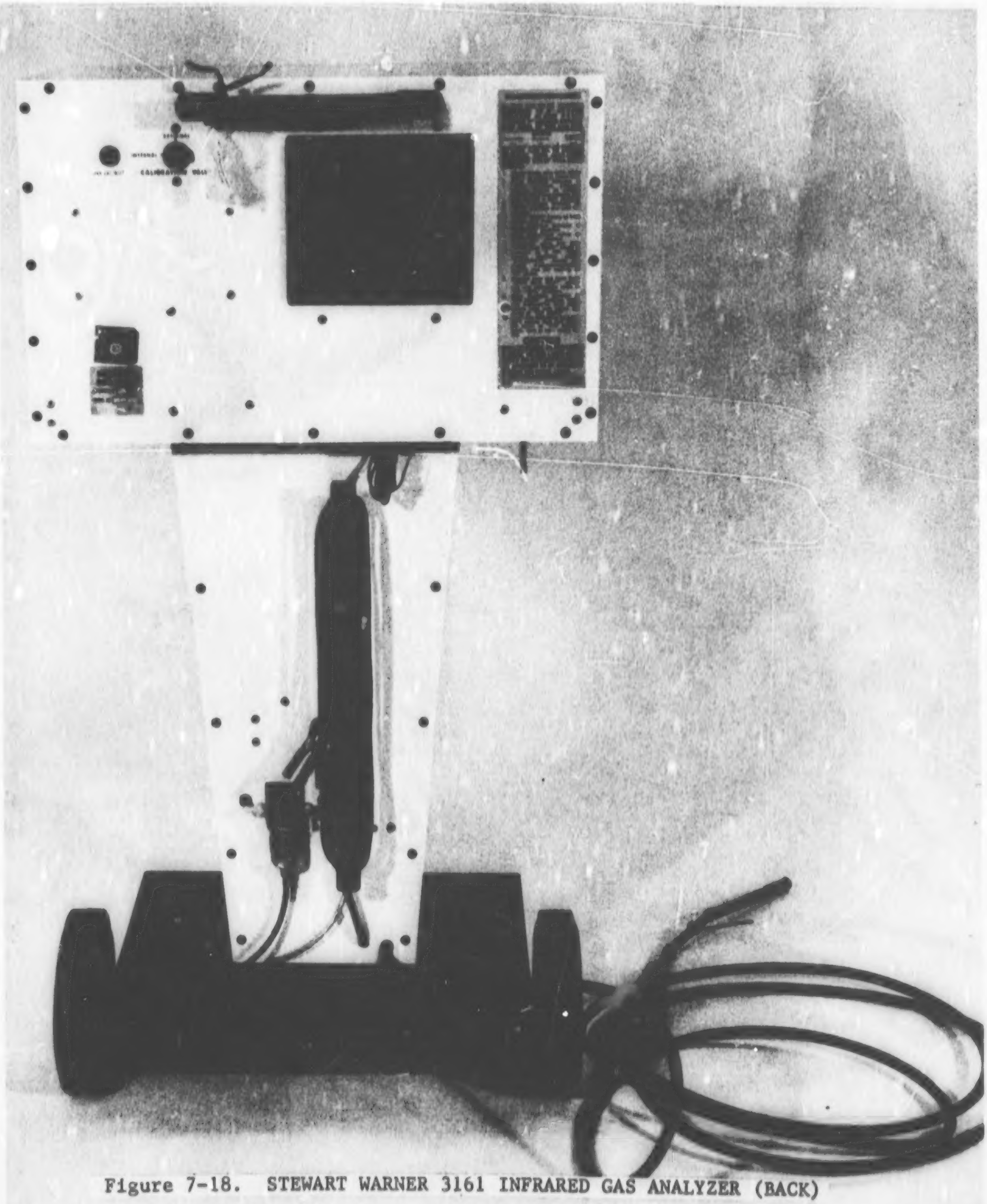
CALIBRATION GAS

Figure 7-18. STEWART WARNER 3161 INFRARED GAS ANALYZER (BACK)

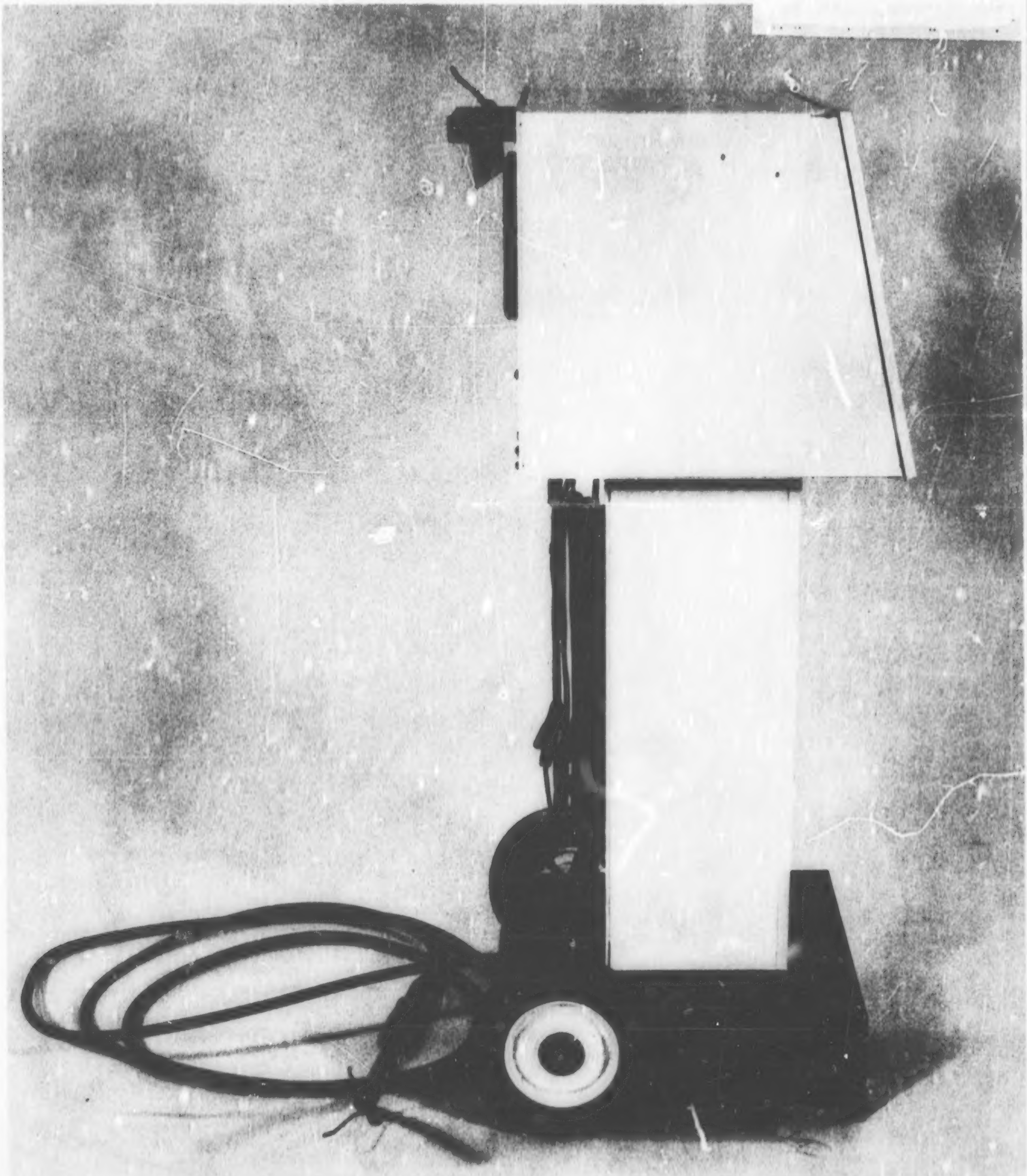

Figure 7-19. STEWART WARNER 3161 INFRARED GAS ANALYZER (RIGHT SIDE)

7.7 SUN EPA 75 EXHAUST PERFORMANCE ANALYZER

Manufacturer - Sun Electric Corporation

Description - HC/CO exhaust analyzer configured as a bench-type unit, mounted (quick disconnect swivel mount) on a four-wheeled cart equipped with two shelves. The analyzer can be used without the cart as a bench top unit. It is not equipped with a top handle so use and movement as a bench top unit would be somewhat more difficult than with the cart.

Dimensions -

Analyzer - Height - 12-1/4 inches
Width - 20-1/4 inches
Depth - 20-1/2 inches

Analyzer and Cart - Height - 48 inches
Width - 24 inches
Depth - 21 inches
Total Weight - 90 lbs.

The mounting hardware that connects the analyzer to the cart allows 30° of the analyzer tilt for best viewing; five steps of angle selection are available.

Material of Construction - Sheet metal cabinets and cart shelves with molded plastic front panel. Cart frame is chrome-plated, round steel tubing.

Color - Blue with red front panel

Mobility - Four, 3-inch diameter swiveling wheels. Left side wheels incorporate manual locks. Mobility is very good. Unit is very stable when in motion due to basic design and C.G. location. Small diameter wheels cause slight problems on rough floors.

Accessories - Sample probe, 25-foot sample hose, operator's manual, chained operating instructions attached to analyzer cabinet.

Control Package -

Front Access - Mode control - four push buttons
1. Off
2. Test
3. Zero
4. Span
CO - HI - push button
CO - LO - push button
CO - Zero - knob
CO - Span - knob
HC - HI - push button
HC - LO - push button

HC - Zero - knob
HC - Span - knob
Low Flow - light

Rear Access -
Operate mode/Gas cal mode - toggle switch
Circuit Breaker - push button - 5 amp
Cal gas inlet

Meters - 8", 90° swing

Ranges - HC - 2000 ppm in 20 ppm increments
500 ppm in 10 ppm increments
CO - 10% in 0.20% increments
2.5% in 0.10% increments

Both HC and CO meters are back-lighted.
High-range figures and divisions are blue on white background.
Low-range figures and divisions are red on white background.
These meters are sensitive to static electricity (soft cloth rubbed over face of meter).

Altitude Compensation - None

Probe - Thirty-inch long convoluted tube with sealed end and perforated sample entrance holes. Circular spring around end of sample line acts as probe handle. Tail pipe clamp used to secure probe.

Filters and Sample Handling - Primary stainless steel particulate filter in primary water trap. Secondary paper element particulate filter in secondary water trap. Primary water trap automatically aspirated by sample pump. Secondary water trap aspirated manually when needed.

Cal Gas Inlet - Rear panel

Power Requirements - 120 VAC 60HZ 4 amps

Operating Principles - Dual cell, single source, dual solid-state detector nondispersive infrared. Chopper modulates infrared and controls reference and signal sychronization LED devices.

Calibration - Span reference button attenuates HC and CO signals. Span set knob used to trim needles to respective set points. Calibration gas can be used but only as a reference test. No span or set pots are available to operator to adjust instrument response to cal gas. Operator's manual indicates acceptable tolerances for both meters. If reading on span gas is outside tolerance, the instrument must be returned to service center for calibration.

Operation and Calibration - Operation instructions located on card chained to the cart. Operation is very simple and straightforward. Rear-mounted gas mode control switch is the only device that can be used incorrectly during operation.

Procedure -

1. Plug in
2. Depress test button
3. Warm up
4. Depress zero button and set zero
5. Depress span button and set to span set
6. Depress test button and use

7.7.1 Operational Performance Comments

The overall layout of this instrument was very good and resulted in a very "useable" instrument. The cart construction and shelf layout were good. The tilt feature incorporated in the cart allowing various analyzer front face angles was very useful and it was noted that this was the only analyzer incorporating this feature. There were no hangers on the unit for the power cord or sample hose but the two cart shelves held both items easily.

The sample hose and probe are of sturdy construction and worked very well during all tests.

Although no range indicator lights were used, the meter scales and range buttons were of a color that, at a distance, was somewhat difficult to determine the range buttons' position and, thus, determination the proper scale to read.

On this unit, the meter scales were printed on the clear meter lens cover and the pointer moved behind the lens, but in front of the back lighted white background translucent lens. This arrangement accentuated the meter parallax problem.

The "Low Flow" indicator light worked well during all tests and seemed to pass the proper sensitivity to indicate flow restriction prior to reading degradation.

The operation and "calibration" of this instrument was greatly simplified by the single span control knob. At no time during laboratory testing did the Sun instrument exceed the manufacturer's span variation specifications for span gas calibration (HC reading within ±60 ppm HC on 2,000 range, and CO reading within ±0.3 percent CO on 10 percent range). It did exceed ±3 percent full scale readings when sampling gases on the low CO range during accuracy determination. Using only span calibration gases and monitoring electronic inter-range correlation, the instrument continually met the manufacturer's specification and, thus, no other span adjustment was indicated. To attempt to achieve highly precise measurements, additional span adjustments would be needed; but for the anticipated accuracy requirements of I/M inspection, this instrument seems to meet the requirements without additional adjustment capability after factory calibration.

In the laboratory tests, this instrument showed warm up times of 9 to 12 minutes except at cold temperatures where it required 24 minutes.

This unit showed zero drift during cycles one and three and 1 percent HC drift with zero CO drift for cycle four. The unit malfunctioned in cycle two during the drift test. At the high test temperature, the unit failed to respond to span gas. It also would not respond to the internal span device.

After returning to normal temperature, the instrument resumed proper operation.

The instrument was found to be the fourth most accurate HC/CO unit in the accuracy determination tests. The specific problem area was the low range CO where 4 percent variations were noted.

High altitude performance indicated, essentially, the same degree of accuracy with the same low range CO problem.

Instrument response times were relatively fast, in the range of 10 to 17 seconds.

This instrument was not sensitive to acetylene or benzene. It showed the highest sensitivity to isobutylene of all instruments. Following isobutylene, it was most sensitive to toluene, methane, and ethylene, in descending sensitivity.

Voltage fluctuation caused 0.2 percent full scale meter deflection for HC and 1.0 percent full scale meter deflection for CO for both ±10 percent voltage change.

The repeatability tests showed 0.8 to 1.6 percent full scale. CO sensitivity to the CO_2 sample gas and 1 to 2 percent full scale. HC sensitivity to the CO sample gas. Additionally, the CO channel indicated a steady 0.4 percent full scale sensitivity to the HC sample gas.

In the vehicle tests, the Sun correlated seventh best with the EPA instrument. No clear pattern of problems was noted. Correlation for low scale HC and CO were generally the same overall with no general deficient areas.

In the durability tests, the Sun completed 101 hours of use. This corresponds to 102,010 ppm-hours of HC exposure and 206 percent-hours of CO exposure.

The failure experienced by this instrument was described as both meters going off-scale (at the high end). The meters could not be rezeroed.

The greatest problem encountered during durability testing was the frequency of changing the secondary paper filter cartridge in the secondary water trap. This filter repeatedly became saturated with water during durability tests. For shorter periods of idle testing or during nonloaded engine testing, the frequency of filter change was greatly reduced. The unit required three filter changes in 101 hours of operation and one manual dumping of the secondary water trap. The primary water trap with atuomatic aspiration worked very well.

The average daily span drift was found to be 3.11 percent full scale for HC and 3.23 percent full scale for CO. These were less than the manufacturer's claim of ±5 percent full scale for 24 hours.

Test data for Sun EPA 75 Exhaust Performance Analyzer are shown in Tables 7-31 through 7-35.

Photographs of this instrument are shown in Figures 7-20, 7-21, and 7-22.

Table 7-31. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: SUN EPA 75

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	12	12	24	9
	LOW	CO	12	12	24	9

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	0	INSTRUMENT	0	1%
	LOW	CO	0	MALFUNCTION	0	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.4	-	0.4	0	0	- 2.0
	LOW	CO	1.2	0	-	0	0	0.4

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 3.65	+ 1.25	- .54	- 0.2
	HIGH	HC/CO	70	+ .58	+ 0.25	+ 1.67	+ 1.0
	HIGH	HC/CO	100	- .64	- 0.6	- .91	- 0.9
	LOW	HC/CO	35	+ 1.7	+ 0.6	+ 1.4	+ 0.4
	LOW	HC/CO	70	+ 1.4	+ 1.0	+ 1.1	+ 0.8
	LOW	HC/CO	100	+ 0.2	+ 0.20	- 4.5	- 4.0
CYCLE 2	HIGH	HC/CO	35	INSTRUMENT	MALFUNCTION		
	HIGH	HC/CO	70				
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO					
	LOW	HC/CO					

Attachment (1)

Table 7-31. DATA COMPOSITE - LABORATORY TEST (Cont'd)

SUN EPA 75

CYCLE 3	HIGH	HC/CO	35	+ 1.7	+ 0.6	- 0.54	- 0.2
	HIGH	HC/CO	70	+ 0.14	+ 0.1	+ 1.54	+ 1.0
	HIGH	HC/CO	100	+ 0.05	+ 0.05	-	-
	LOW	HC/CO	35	- 1.12	- 0.4	- 2.85	- 1.2
	LOW	HC/CO	70	+ 0.27	+ 0.2	+ 0.57	+ 0.4
	LOW	HC/CO	100	- 0.2	- 0.2	+ 0.45	+ 0.4
CYCLE 4	HIGH	HC/CO	35	+ 7.56	+ 2.6	- 0.53	- 0.2
	HIGH	HC/CO	70	- 0.56	- 0.4	+ 1.5	+ 1.0
	HIGH	HC/CO	100	+ 0.06	+ 0.5	- 0.54	- 0.5
	LOW	HC/CO	35	+ 2.26	+ 0.8	- 4.7	-20
	LOW	HC/CO	70	+ 1.3	+ 1.0	- 4.7	- 4.0
	LOW	HC/CO	100	+ 0.2	+ 0.2	- 4.5	- 4.0
HIGH ALTITUDE	HIGH	HC/CO	35	+ 4.65	+ 1.6	- .54	- 0.2
	HIGH	HC/CO	70	- 1.97	- 1.4	+ 3.1	+ 2.0
	HIGH	HC/CO	100	- .50	- 0.45	+ 1.1	+ 1.0
	LOW	HC/CO	35	- 2.82	- 1.0	- 4.8	- 2.0
	LOW	HC/CO	70	+ .27	+ 0.2	- 5.7	- 4.0
	LOW	HC/CO	100	+ .20	+ 0.2	- 4.5	- 4.0
	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1709	11.4	INSTRUMENT	8.05	16.0
	HIGH	CO	8.1	10.6	MALFUNCTION	7.6	17.35
HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	8	90	15	38
6750 Feet Altitude	LOW	0	0	5	72	12	35

Table 7-31. DATA COMPOSITE - LABORATORY TEST (Cont'd)

SUN EPA 75

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	.2	.2
	115V	HIGH	CO	1.0	1.0

Table 7-32. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: SUN EPA 75

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	7	16	7	10
		CO	6	16	7	10

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	0	0	2.2	2.0
		CO	0.4	0.8	4.4	0.4

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	--	0	0	0	0
		CO	0.8	0.4	--	0	0.4	0.4

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.8	--	2.0	1.0	2.0	3.0
		CO	0.8	0.4	---	0	3.6	1.2

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	--	1.0	0	0	0
		CO	1.6	0.4	---	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	1.0	---	0.2	1.0	0	0
		CO	1.2	0.4	---	0.8	0	0

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1709	20.5	15	8.5	9
		CO	8.1	20	16	8	7

SUN EPA 75

Table 7-32. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 5.84	+ 2.00	- 3.23	- 1.20
	HIGH	HC/CO	70	- 0.92	- 0.65	+ 1.54	+ 1.00
	HIGH	HC/CO	100	- 0.11	- 0.10	0	0
	LOW	HC/CO	35	- 2.82	+ 1.00	- 4.76	- 2.0
	LOW	HC/CO	70	- 0.83	- 0.60	- 8.57	- 6.0
	LOW	HC/CO	100	- 2.41	- 2.40	- 9.09	- 8.0
CYCLE 2	HIGH	HC/CO	35	+ 7.30	+ 2.50	+ 0.81	+ 0.30
	HIGH	HC/CO	70	- 0.21	- 0.15	+ 1.54	+ 1.0
	HIGH	HC/CO	100	+ 0.45	+ 0.40	- 1.09	- 1.0
	LOW	HC/CO	35	0	0	0	0
	LOW	HC/CO	70	- 0.83	- 0.60	- 2.29	- 1.60
	LOW	HC/CO	100	- 1.41	- 1.40	- 2.27	- 2.0
CYCLE 3	HIGH	HC/CO	35	+ 7.30	+ 2.50	+ 0.81	+ 0.30
	HIGH	HC/CO	70	- 0.92	- 0.65	+ 2.31	+ 1.5
	HIGH	HC/CO	100	- 0.11	- 0.10	0	0
	LOW	HC/CO	35	+ 1.70	+ 0.60	+ 0.95	+ 0.40
	LOW	HC/CO	70	- 0.83	- 0.60	0	0
	LOW	HC/CO	100	- 3.16	- 3.20	0	0
CYCLE 4	HIGH	HC/CO	35	+ 8.76	+ 3.00	- 1.08	- 0.40
	HIGH	HC/CO	70	+ 0.42	+ 0.30	+ 1.85	+ 1.20
	HIGH	HC/CO	100	= 1.23	+ 1.10	0	0
	LOW	HC/CO	35	- 3.39	- 1.20	+ 1.90	+ 0.80
	LOW	HC/CO	70	- 1.10	- 0.80	- 1.71	- 1.20
	LOW	HC/CO	100	- 3.42	- 3.40	- 0.93	- 0.80

Table 7-33. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

SUN EPA 75

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	500/2.5	HC/CO	50	+ 6.82	+ 1.34	+ 22.81	+ 5.2
	500/2.5	HC/CO	30	+ 4.64	+ 1.02	+ 23.08	+ 1.2
	500/2.5	HC/CO	IDLE	- 8.56	- 5.62	+ 48.65	+ 7.2
CYCLE 2	500/2.5	HC/CO	50	+ 29.39	+ 5.36	+ 29.03	+ 7.2
	500/2.5	HC/CO	30	+ 16.7	+ 3.72	+ 21.43	+ 1.2
	500/2.5	HC/CO	IDLE	+ 1.01	+ 0.52	+ 27.55	+ 10.8
CYCLE 3	500/2.5	HC/CO	50	+ 26.1	+ 4.76	+ 18.64	+ 4.4
	500/2.5	HC/CO	30	+ 1.55	+ 0.4	+ 50.0	+ 2.4
	500/2.5	HC/CO	IDLE	- 6.83	- 3.96	+ 33.8	+ 9.6
CYCLE 4	500/2.5	HC/CO	50	+ 51.83	+ 9.9	+ 45.83	+ 8.8
	500/2.5	HC/CO	30	+ 59.09	+ 11.96	+ 63.64	+ 2.8
	500/2.5	HC/CO	IDLE	+ 52.35	+ 20.96	+ 69.9	+ 28.8
LEAN MODE CYCLE 1	500/2.5	HC/CO	50	+ 53.75	+ 8.74	+ 7.69	+ 2.0
	500/2.5	HC/CO	30	+ 31.58	+ 5.76	+ 15.38	+ 0.8
	2000/2.5	HC/CO	IDLE	+ 29.38	+ 10.22	+ 47.06	+ 3.2
CYCLE 2	500/2.5	HC/CO	50	+ 21.33	+ 4.5	+ 40.0	+ 8.0
	500/2.5	HC/CO	30	+ 22.96	+ 4.78	+ 25.0	+ 1.2
	2000/2	HC/CO	IDLE	+ 4.46	+ 1.5	+ 47.37	+ 3.6
CYCLE 3	500/2.5	HC/CO	50	+ 21.33	+ 4.5	+ 12.9	+ 3.2
	500/2.5	HC/CO	30	+ 42.68	+ 7.06	+ 66.67	+ 2.4
	2000/2.5	HC/CO	IDLE	+ 0.22	+ 0.07	+ 52.94	+ 3.6
CYCLE 4	500/2.5	HC/CO	50	+ 80.17	+ 13.26	+ 70.73	+ 11.6
	500/2.5	HC/CO	30	+ 69.88	+ 12.34	+ 63.64	+ 2.8
	500/2.5	HC/CO	IDLE	+ 21.83	+ 17.2	+163.16	+ 12.4

Table 7-33. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

SUN EPA 75

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	500/2.5	HC/CO	50	+ 18.69	+ 4.0	+ 19.72	+ 5.6
	500/2.5	HC/CO	30	+ 17.65	+ 4.5	+ 4.17	+ 0.4
	500/10	HC/CO	IDLE	+ 15.09	+ 10.36	+ 13.79	+ 6.3
CYCLE 2	500/2.5	HC/CO	50	+ 60.82	+ 12.48	+ 29.31	+ 6.8
	500/2.5	HC/CO	30	+ 55.14	+ 12.44	+ 35.71	+ 2.0
	500/10	HC/CO	IDLE	+ 30.77	+ 19.06	+ 23.71	+ 9.2
CYCLE 3	500/2.5	HC/CO	50	+ 15.07	+ 2.62	+ 25.0	+ 6.0
	500/2.5	HC/CO	30	+ 13.52	+ 2.62	+ 41.67	+ 2.0
	500/10	HC/CO	IDLE	+ 24.6	+ 12.28	+ 24.26	+ 8.2
CYCLE 4	500/2.5	HC/CO	50	+ 31.31	+ 5.98	+ 19.72	+ 5.6
	500/2.5	HC/CO	30	+ 32.7	+ 6.9	+ 38.46	+ 2.0
	500/10	HC/CO	IDLE	+ 35.98	+ 18.52	- 63.56	- 21.8

Table 7-34. DIAGNOSTIC TEST

SUN EPA 75

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	500	HC	1100	1133	- 2.91	- 1.65
	10%	CO	2.50	2.15	+ 16.28	+ 3.5
NORMAL IDLE	500	HC	380	358	+ 6.15	+ 4.4
	10%	CO	2.55	2.04	+ 25.0	+ 5.1
IGNITION ADVANCE	500	HC	325	358	- 9.22	- 6.6
	10%	CO	2.70	2.08	+ 29.81	+ 6.2
IGNITION RETARD	500	HC	380	316	+ 20.25	+ 12.8
	10%	CO	2.95	2.39	+ 23.43	+ 5.6

Table 7-35. DURABILITY TEST DATA

INSTRUMENT: SUN EPA 75

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	101
HC EXPOSURE (PPM-HRS.)	102,010
CO EXPOSURE (%-HRS.)	206
NO EXPOSURE (PPM-HRS.)	10,504
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	0
SHOCK TEST FAILURE RATE (Failure/Day %)	0
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	0
HC SPAN	0
CO ZERO	0
CO SPAN	0
AVERAGE DAILY SPAN DRIFT	
HC%	3.11
CO%	3.23
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER TOTAL PER 100 HRS.	 3 2.97
B DRAIN HOSE TOTAL PER 100 HRS.	 -- --
C REZERO TOTAL PER 100 HRS.	 -- --
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	 1 0.99
E. OTHER TOTAL PER 100 HRS.	 -- --

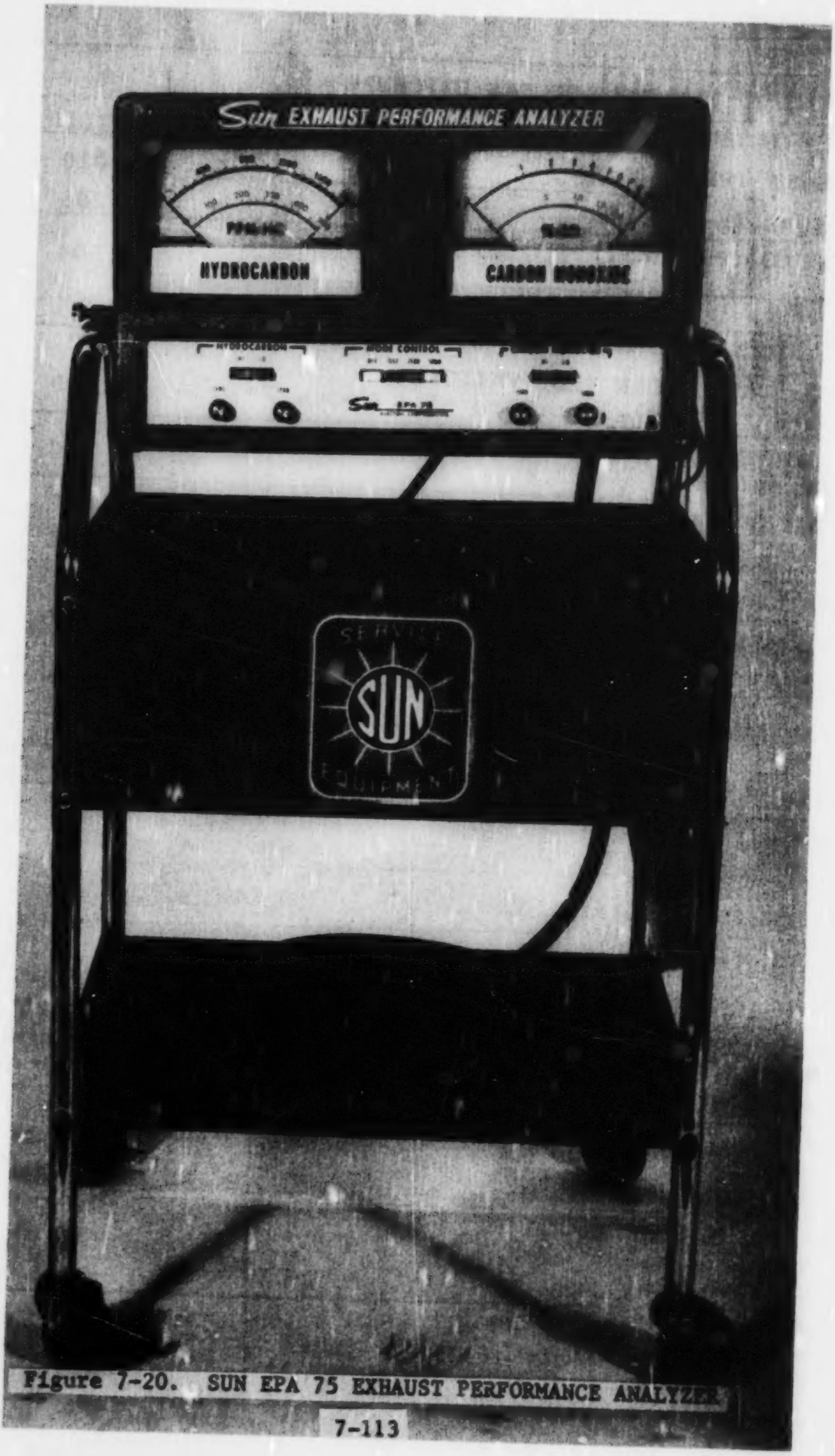
Sun EXHAUST PERFORMANCE ANALYZER
HYDROCARBON
CARBON MONOXIDE
MODE CONTROL
SERVICE
SUN
EQUIPMENT

Figure 7-20. SUN EPA 75 EXHAUST PERFORMANCE ANALYZER

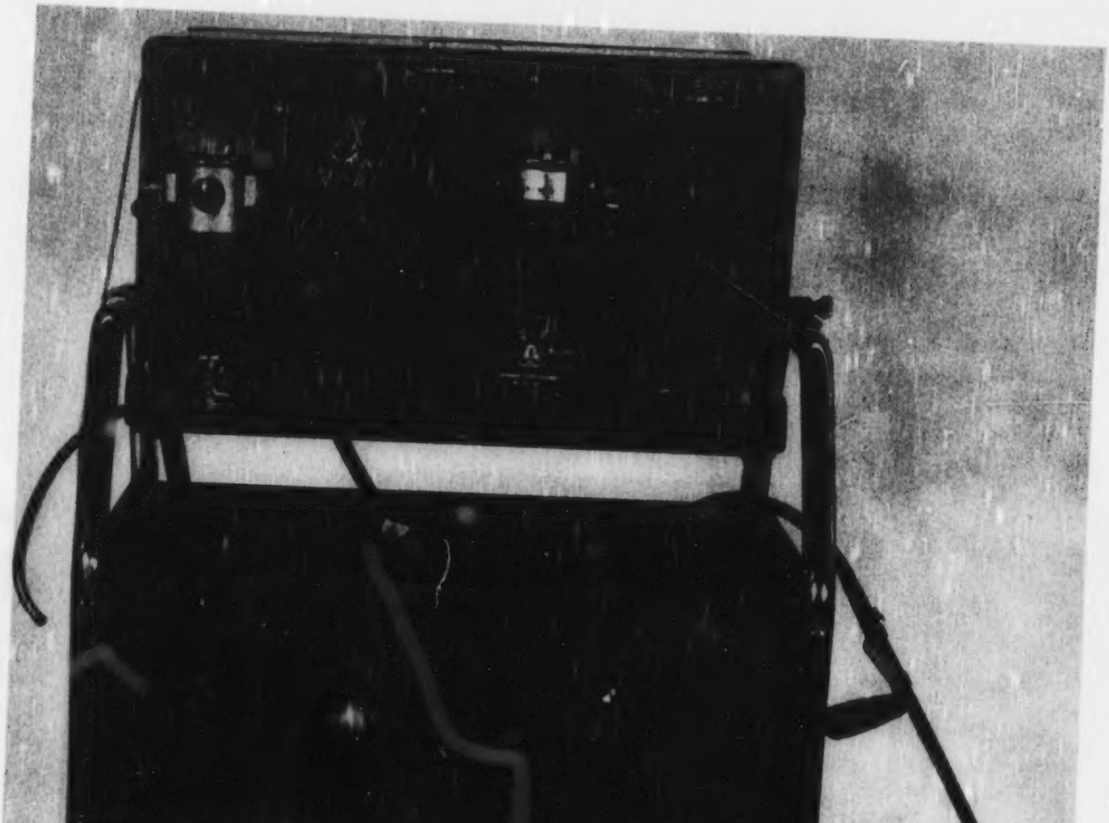

Figure 7-21. SUN EPA 75 EXHAUST PERFORMANCE ANALYZER (BACK)

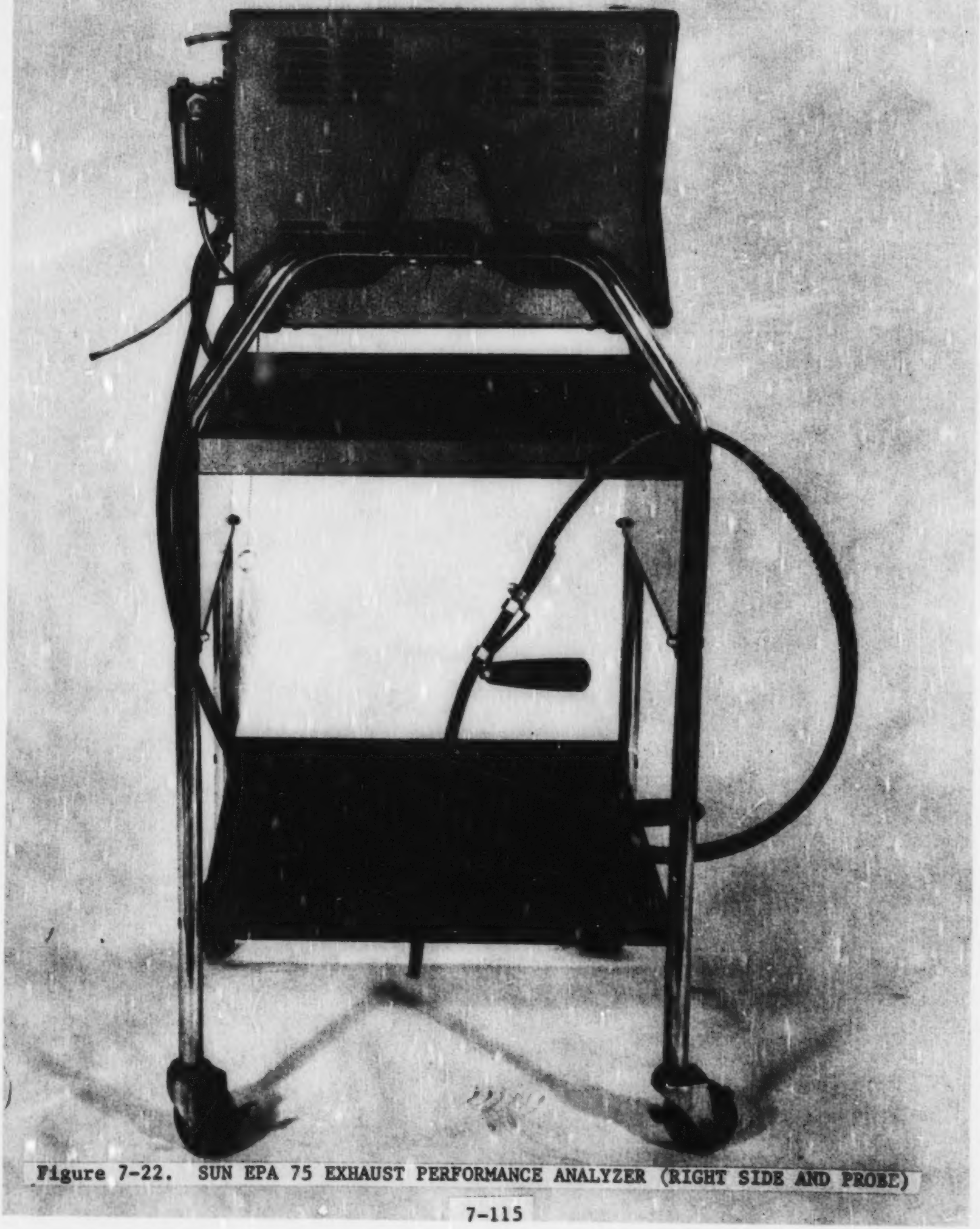

Figure 7-22. SUN EPA 75 EXHAUST PERFORMANCE ANALYZER (RIGHT SIDE AND PROBE)

7.8 MOPAR IIIC EXHAUST EMISSION ANALYZER

Manufacturer - Chrysler Corporation

Description - HC/CO exhaust analyzer configured as a bench to unit, but available with a two-wheel cart. The analyzer can be used with or without the cart with equal ease. The cart incorporates storage areas.

Dimensions -

Analyzer - Height - 9 inches
Width - 13 inches
Depth - 10 inches
Weight - 20 lbs.

Cart - Height - 38 inches
Width - 15 inches
Depth - 15 inches
Weight - 30 lbs.

The cart incorporates a top drawer and a lower storage area with a snap closing door.

Material of Construction - Main analyzer cabinet is aluminum sheet. Cart is sheet metal. Method of joining welding and screws.

Color - Analyzer - Blue with silver front - Cart - red

Mobility - Two rear-mounted, 7-inch wheels. Round tube cart handle is at top rear of instrument. Mobility and stability of this combination is very good. Low C.G. gives very stable feel.

Accessories - Tail pipe probe with 25-foot sample hose (two pieces), water trap, operator's manual.

Control Package -

Front Access -
HC - course zero adjust (screw)
HC - fine zero adjust (knob)
HC - span adjust (screw)
HC - Cal adjust (screw)
HC - range switch (two-position toggle)
CO - course zero adjust (screw)
CO - fine zero adjust (knob)
CO - span adjust (screw)
CO - cal adjust (screw)
CO - range switch (two-position toggle)

POWER - push button incorporating indicating lamp
CALIBRATE CHECK - push button
LOW FLOW - light

No external fuses or breakers (external housing must be removed to replace lamp fuse)

Rear access -
Recorder jack

Meters - 6-inch, 90° swing

High scale - green graduations - black figures
Low scale - red graduations - black figures
White background
Meter visibility and readability is rated as good

Ranges - HC - 2000 ppm in 50 ppm increments
300 ppm in 50 ppm increments
CO - 10% in 0.2% increments
0.5% in 0.01% increments

The meters on this instrument were not sensitive to static electricity (soft cloth rubbed against lens).

Altitude Compensation - On chart contained in operator's manual. Requires use of correction factor. Correction not needed if gas calibration used at altitude in question.

Probe - Three-foot convoluted tube with sealed end and perpendicular gas entrance holes. Tube has handle at mid-span and adjustable tail pipe clamp.

Filters and Sample Handling - No filters are used. Steel water trap requiring periodic emptying. Internal pump moves sample from vehicle to analyzer bench.

Cal Gas Inlet - Front mount, same as sample inlet

Power Requirements - 115 BAC 60HZ 100 watts

Operating Principles - Nondispersive single beam infrared instrument using narrow-band infrared optical filters. Incorporates a sample cell reference filter to cancel the effects of dust, particulate and smoke in the sample cell.

Calibration - Electronic reference signal by "calibrate check" button on front panel and calibration reference points on meter faces. Gas calibration through front panel port utilizing span adjustment screws on front panel.

Operation and Calibration - Very easy operating and calibrating instructions on analyzer cart.

1. Warm up
2. Set zero
3. Push calibration check button

4. If OK, ready for use
5. If not, gas calibration through front port using HC and CO span screws
6. Adjust calibrate check points
7. Ready for use.

7.8.1 Operational Performance Comments

This unit is identical to the Scott IIIC except for the logo. The relative degree of inter-instrument correlation was demonstrated by the Scott and Mopar IIIC tests.

This unit has excellent mobility while on its cart due to C.G. location, handle placement and wheel size. In addition, the unit is very handy used as bench top model due to its small size. The analyzer fits freely but tightly into a tilted recess at the top of the cart. The analyzer is equipped with a top-mount strap carrying handle that facilitates removal from the cart for portable use. The cart contains a top-mounted drawer that is handy for manual storage and a bottom storage cabinet with snap closing door. This cabinet works very well for probe, trap and sample hose storage, although hose hangers are mounted on the cart and rear.

This analyzer uses a turbine-type sample pump differing from the typical diaphragm pump found on other analyzers. This results in a very low level of both noise and vibration.

This unit, without benefit of any form of particulate filter, has an unusual sample handling system that appears to be relatively unsusceptible to water and particulate accumulation.

This system uses only a single metal cooling tube on its sample hose to collect moisture.

This tube acts as a system low point and collects condensed sample moisture which must be dumped out periodically. The probe used on this unit is a convoluted tube approximately 3 feet long.

The sample hose, made of clear unreinforced plastic tubing, periodically filled with water during durability testing. When the flow restriction light indicated low flow, the hose was drained and sampling returned to normal. The material used for this hose was susceptible to melting when placed against a hot exhaust pipe.

This unit, in general, was very easy to use and demonstrated exceptional dependability.

The analytical system on this unit consisted of a single sample cell and rotating filter wheel.

This unit demonstrated fast response during the laboratory tests and vehicle test sequences.

This unit and Scott IIIC incorporated lower ranges than any other instrument tested. Because of its extremely low range, it is more applicable for use with catalytic converter-equipped cars than the other instruments.

This instrument had a minimum number of controls and the simplest and most straightforward operation and calibration procedures.

A single front panel gas port was used for both sample and calibration gases. Range selection was made through use of individual HC and CO toggle switches. Range indication other than switch position was not utilized and this was the only negative aspect to the control/display function.

In the laboratory tests, this unit showed acceptable warm up times. Zero drift performance at normal laboratory temperatures was reasonable considering the low ranges incorporated in this unit. Zero drift for CO at high temperature was 80 percent full scale, indicating extreme stability sensitivity to high temperatures. Low temperature zero drift was greater than that at normal temperatures but an order of magnitude lower for CO than that at high temperature. (NOTE: Both the Scott IIIC and Mopar IIIC showed the same zero drift temperature sensitivity.)

The Mopar IIIC showed good analytical accuracy tying with the Scott IIIC for fith most accurate overall in the accuracy determination tests.

In the high altitude tests, the CO accuracy readings slipped significantly, most prominently during high range tests. (The Scott IIIC showed the same tendency.)

Instrument response time was fast, on the order of 11 seconds or less and was relatively consistent during laboratory tests.

This instrument was not responsive to acetylene and only marginally responsive to benzene. It was most responsive to isobutylene, followed by toluene, methane and ethylene.

Voltage variation caused no meter reading variation.

The HC scale was noted to be responsive to CO_2 ranging from 0.67 to 3.33 percent full scale meter deflection. The CO meter showed essentially no response to the CO_2 sample in the repeatability test cycle.

The CO meter indicated a range of response of 0.4 to 2 percent full scale to the HC sample during the repeatability cycles. NO response was slightly less significant than that seen on the Scott IIIC.

The CO_2 response pattern was also seen in the Scott IIIC but the NO response was more dominant.

In the vehicle tests, the Mopar IIIC was found to correlate tenth best of all instruments with the EPA bench. HC correlation seemed to cause the most trouble, especially on low range during the standard and lean modes. CO correlation was poor during rich modes. This unit survived the durability test for 528 hours of operation.

This corresponds to HC exposure levels of 470,976 ppm-hours and CO exposure of 227 percent-hours. The instrument showed relatively good day-to-day stability in the durability test with an average daily span drift of 2.3 percent full scale for HC and 1.3 percent full scale for CO. Resistance to vibration and shock was good with only 2 days of shock test failure (resulting in 73 percent full scale meter variation) noted for the total durability test. This corresponds to 6.06 failure per day. CO span failure dominated.

This instrument required no maintenance other than hose and water trap draining during the duration of all tests.

During the durability tests, the hose required draining 26 times. This corresponds to a rate of 4.92 servicings per 100 hours of operation. During the durability tests, failure resulted from the CO reading becoming totally unreliable. After additional testing, the CO reading remained up-scale during attempted rezeroing. The failure seemed to be of an electrical nature and could be related to a meter failure. No loss in response time was noted as seen in the Scott, but total test time and exposure for the Mopar was significantly less.

Test data for Mopar IIIC Exhaust Emission Analyzer are shown in Tables 7-36 through 7-40.

Photographs of this instrument are shown in Figures 7-23, 7-24, and 7-25.

Table 7-36. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: MOPAR IIIC

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	18	12	22	17
	LOW	CO	16	12	22	15

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	0	3.3	2.0	4.0
	LOW	CO	0	80.0	6.0	2.2

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	3.33	-	0.33	0	0	0
	LOW	CO	4.0	10.0	-	0	10.0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 4.29	+ 1.4	- 0.54	- 0.2
	HIGH	HC/CO	70	- 1.49	- 1.0	+ 2.3	+ 1.5
	HIGH	HC/CO	100	- 0.29	- .25	+ 2.17	+ 2
	LOW	HC/CO	35	0	0	+ 1.25	+ 4.2
	LOW	HC/CO	70	0	0	+ .07	+ .04
	LOW	HC/CO	100	+ 3.45	+ 3.33	-20	- 2.0
CYCLE 2	HIGH	HC/CO	35	+ 2.76	+ 0.9	- 3.23	- 1.2
	HIGH	HC/CO	70	- 2.6	- 1.75	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.12	- 0.1	+ 2.17	+ 2.0
	LOW	HC/CO	35	+ 1.0	+ 0.33	- 4.11	- 1.30
	LOW	HC/CO	70	+ 0.51	+ 0.5	- 3.38	- 1.96
	LOW	HC/CO	100	+ 1.72	+ 1.67	0	0

Table 7-36. DATA COMPOSITE - LABORATORY TEST (Cont'd)

MOPAR IIIC

CYCLE 3	HIGH	HC/CO	35	+ 4.29	+ 1.4	- 0.54	- 0.2
	HIGH	HC/CO	70	- 1.15	- 0.75	+ 1.54	+ 1.0
	HIGH	HC/CO	100	+ .12	+ 0.1	+ 3.26	+ 3.0
	LOW	HC/CO	35	+ 2.0	+ .67	+ 4.23	+ 1.42
	LOW	HC/CO	70	0	0	- .96	- .56
	LOW	HC/CO	100	+ 0.34	+ .33	+ 2.0	+ 2.0
CYCLE 4	HIGH	HC/CO	35	+ 4.23	+ 1.4	- 1.88	- 0.7
	HIGH	HC/CO	70	- 2.6	- 1.75	+ 1.54	+ 1.0
	HIGH	HC/CO	100	0	0	+ 3.26	+ 3.0
	LOW	HC/CO	35	+ 2.0	+ 0.67	-10.66	- 3.58
	LOW	HC/CO	70	- 2.54	- 1.67	- 1.66	- 0.96
	LOW	HC/CO	100	+ 2.41	+ 2.33	+ 2.0	+ 2.0
HIGH ALTITUDE	HIGH	HC/CO	35	+ .31	+ .1	-18.35	- 7.2
	HIGH	HC/CO	70	- 3.35	- 2.25	-16.92	-11.0
	HIGH	HC/CO	100	- 0.35	- 0.3	-18.48	-17.0
	LOW	HC/CO	35	0	0	- 1.73	- 0.58
	LOW	HC/CO	70	- 3.55	- 2.33	- 5.11	- 2.96
	LOW	HC/CO	100	+ 0.69	+ 0.67	- 2.0	- 2.0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1627	10.1	11.5	7.25	6.5
	HIGH	CO	8.1	9.5	10.0	7.25	6.25

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	3	6	88	17	42
6750 Feet Altitude	LOW	0	0	9	82	15	40

Table 7-36. DATA COMPOSITE - LABORATORY TEST (Cont'd)

MOPAR IIIC

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0	0
	115V	HIGH	CO	0	0

Table 7-37. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: MOPAR IIIC

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	14	29	28	23
		CO	12	29	25	22

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	5.0	4.33	7.0	0.67
		CO	3.4	2.0	4.0	0.2

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	--	0	0	0.04	0
		CO	0	2.0	--	0	0	2.0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	3.33	--	0	0	0	0
		CO	0	0.4	---	0	1.0	0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	1.67	--	0	0	0	0
		CO	0	0	--	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.67	---	1.67	0	0.67	0
		CO	0.4	1.0	---	0	2.0	0.6

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1627	15	12	8.5	9.5
		CO	8.1	15.5	12	5	7

Table 7-37. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

MOPAR IIIC

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 1.23	+ 0.40	- 0.54	- 0.20
	HIGH	HC/CO	70	- 5.20	- 3.50	+ 2.31	+ 1.50
	HIGH	HC/CO	100	- 2.77	- 2.35	+ 1.63	+ 1.50
	LOW	HC/CO	35	+ 2.0	+ 0.67	± 1.85	+ 0.62
	LOW	HC/CO	70	+ 1.52	+ 1.00	- 1.66	- 0.96
	LOW	HC/CO	100	+ 3.45	+ 3.33	+ 2.0	+ 2.00
CYCLE 2	HIGH	HC/CO	35	+ 4.29	+ 1.40	- 3.23	- 1.20
	HIGH	HC/CO	70	- 1.86	- 1.25	0	0
	HIGH	HC/CO	100	+ 0.24	+ 0.20	+ 1.09	+ 1.0
	LOW	HC/CO	35	+ 1.0	+ 0.33	0	0
	LOW	HC/CO	70	+ 0.51	+ 0.33	- 0.28	- 0.16
	LOW	HC/CO	100	+ 2.41	+ 2.33	+ 4.0	+ 4.0
CYCLE 3	HIGH	HC/CO	35	+ 5.83	+ 1.9	- 1.88	- 0.7
	HIGH	HC/CO	70	+ 0.83	+ 0.7	+ 0.54	+ 0.5
	HIGH	HC/CO	100	0	0	+ 0.66	+ 0.22
	LOW	HC/CO	35	0	0	- 0.62	- 0.36
	LOW	HC/CO	70	+ 3.10	+ 3.0	+ 1.6	+ 1.6
	LOW	HC/CO	100	- 1.49	- 1.0	+ 1.54	+ 1.0
CYCLE 4	HIGH	HC/CO	35	+ 5.83	+ 1.90	- 2.69	- 1.00
	HIGH	HC/CO	70	- 0.37	- 0.25	+ 0.77	+ 0.50
	HIGH	HC/CO	100	+ 1.42	+ 1.20	+ 0.54	+ 0.50
	LOW	HC/CO	35	0	0	- 1.19	- 0.40
	LOW	HC/CO	70	+ 2.54	+ 1.67	- 1.72	- 1.00
	LOW	HC/CO	100	+ 2.07	+ 2.00	0	0

Table 7-33. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

MOPAR IIIC

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	300/10	HC/CO	50	- 39.81	- 18.3	+ 12.70	+ 0.8
	300/.5	HC/CO	30	- 40.55	- 20.47	+ 3.17	+ 0.8
	300/10	HC/CO	IDLE	- 29.72	- 23.97	- 5.17	- 0.6
CYCLE 2	300/.5	HC/CO	50	- 42.18	- 18.97	0	0
	300/.5	HC/CO	30	- 43.16	- 20.63	- 9.90	- 2.0
	300/10	HC/CO	IDLE	- 39.65	- 35.03	+ 2.8	+ 0.3
CYCLE 3	300/10	HC/CO	50	- 34.29	- 14.27	+ 50.0	+ 2.0
	300/.5	HC/CO	30	- 47.33	- 20.97	+ 7.69	+ 2.0
	300/10	HC/CO	IDLE	- 30.43	- 22.6	+ 17.19	+ 2.2
CYCLE 4	300/10	HC/CO	50	- 45.51	- 18.93	- 14.86	- 1.0
	300/.5	HC/CO	30	- 64.87	- 27.7	+ 42.86	+ 12.0
	300/10	HC/CO	IDLE	- 42.53	- 33.3	+ 15.38	+ 1.6
LEAN MODE CYCLE 1	300/10	HC/CO	50	- 35.91	- 18.3	+ 4.84	+ 6.0
	300/.5	HC/CO	30	- 39.33	- 19.67	- 1.64	- 0.02
	300/10	HC/CO	IDLE	- 26.16	- 4.96	+ 18.64	+ 2.2
CYCLE 2	300/.5	HC/CO	50	- 42.42	- 20.13	- 15.38	- 1.0
	300/.5	HC/CO	30	- 39.35	- 19.47	- 9.09	- 2.0
	300/10	HC/CO	IDLE	- 31.5	- 5.34	+ 13.21	+ 0.7
CYCLE 3	300/10	HC/CO	50	- 53.74	- 23.23	+ 4.94	+ 0.4
	300/.5	HC/CO	30	- 60.98	- 26.03	+ 92.31	+ 2.4
	300/10	HC/CO	IDLE	- 46.57	- 8.72	+ 25.0	+ 1.3
CYCLE 4	300/10	HC/CO	50	- 54.1	- 23.97	+ 53.85	+ 14.0
	300/.5	HC/CO	30	- 67.53	- 27.73	+ 53.85	+ 14.0
	300/10	HC/CO	IDLE	- 31.22	- 30.37	+ 87.5	+ 2.8

Table 7-38. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

MOPAR IIIC

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	300/10	HC/CO	50	- 29.03	- 13.63	- 5.66	- 0.3
	300/.5	HC/CO	30	- 30.67	- 15.33	- 48.42	- 18.4
	2000/10	HC/CO	IDLE	- 58.9	- 22.22	+153.09	+ 24.8
CYCLE 2	300/10	HC/CO	50	- 43.04	- 18.13	+ 5.26	+ 0.4
	300/.5	HC/CO	30	- 53.74	- 23.23	+ 50.0	+ 14.0
	2000/10	HC/CO	IDLE	- 24.41	- 3.96	+ 17.98	+ 6.4
CYCLE 3	300/10	HC/CO	50	- 24.84	- 10.47	- 11.76	- 0.8
	300/.5	HC/CO	30	- 33.65	- 14.37	0	0
	2000/10	HC/CO	IDLE	- 23.18	- 3.62	+ 7.14	+ 2.4
CYCLE 4	300/10	HC/CO	50	- 12.18	- 5.13	- 5.80	- 0.4
	300/.5	HC/CO	30	- 17.25	- 7.37	- 21.43	- 6.0
	2000/10	HC/CO	IDLE	- 1.31	- 0.21	+ 15.26	+ 4.9

Table 7-39. DIAGNOSTIC TEST

MOPAR IIIC

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1100	1142	+ 16.28	+ 3.5
	10%	CO	2.40	2.13	+ 12.68	+ 2.7
NORMAL IDLE	2000	HC	380	467	- 18.63	- 4.35
	10%	CO	2.40	2.11	+ 13.74	+ 2.9
IGNITION ADVANCE	300	HC	250	365.9	- 31.68	- 38.63
	10%	CO	250	2.15	+ 16.28	+ 3.5
IGNITION RETARD	2000	HC	400	449.9	- 11.09	- 2.50
	10%	CO	2.78	2.46	+ 13.01	+ 3.2

Table 7-40. DURABILITY TEST DATA

INSTRUMENT: MOPAR IIIC

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	528
HC EXPOSURE (PPM-HRS.)	470,976
CO EXPOSURE (%-HRS.)	227
NO EXPOSURE (PPM-HRS.)	55,440
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	2
SHOCK TEST FAILURE RATE (Failure/Day %)	6.06
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	0
HC SPAN	0
CO ZERO	0
CO SPAN	2
AVERAGE DAILY SPAN DRIFT	
HC%	2.3
CO%	1.3
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	--
PER 100 HRS.	--
B DRAIN HOSE	
TOTAL	26
PER 100 HRS.	4.92
C REZERO	
TOTAL	--
PER 100 HRS.	--
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	--
PER 100 HRS.	--

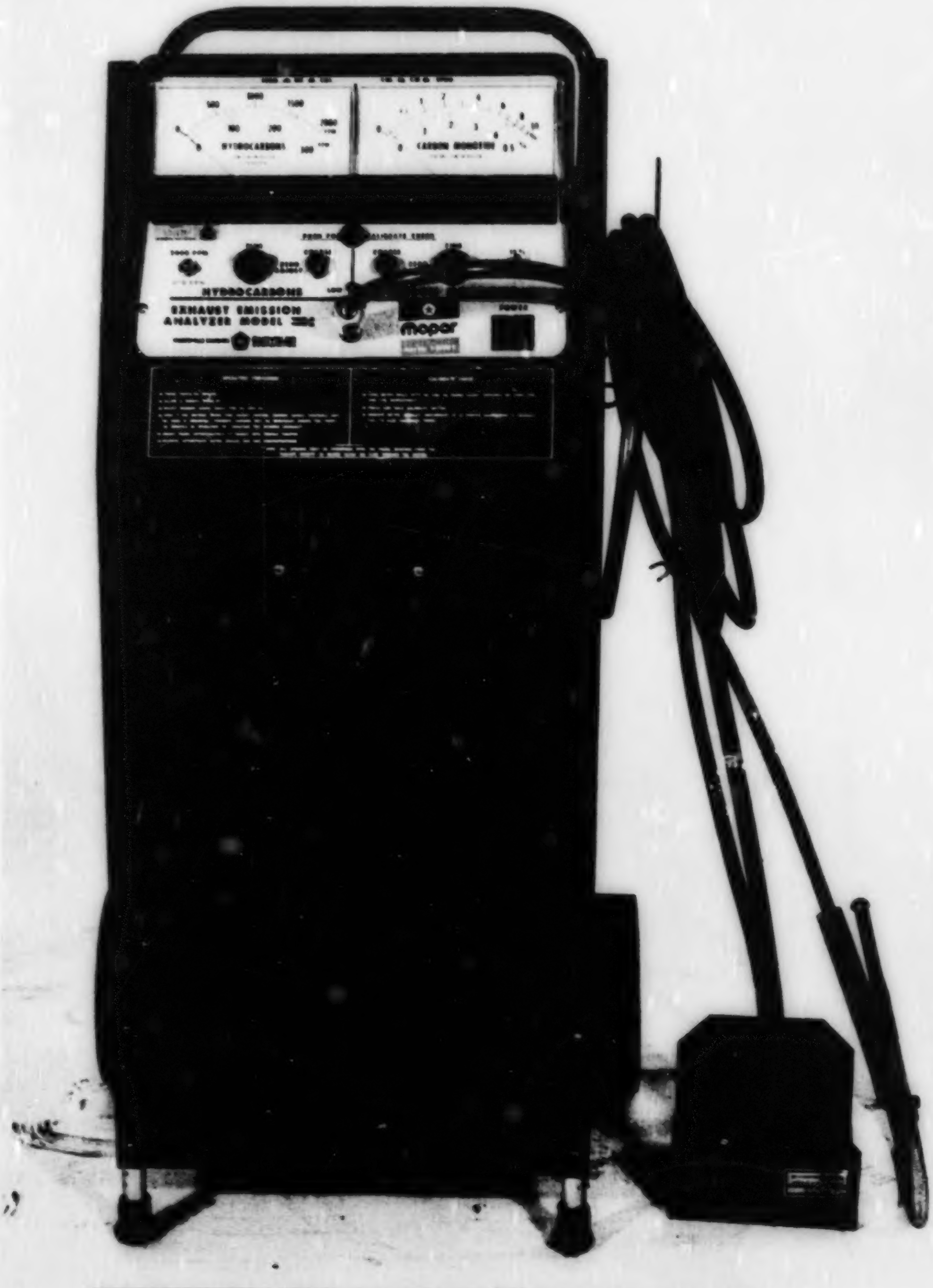

Figure 7-23. MOPAR IIIC EXHAUST EMISSION ANALYZER

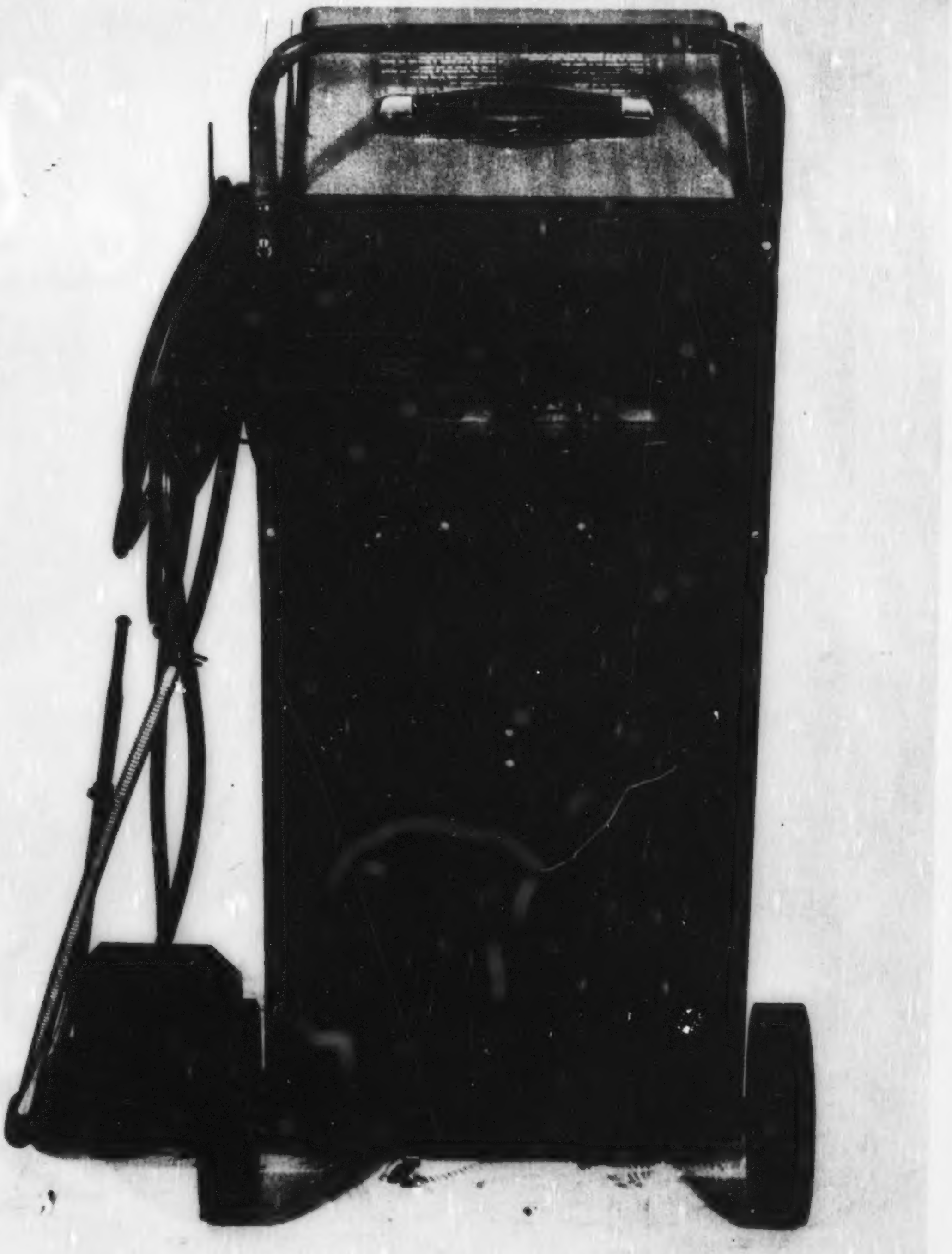

Figure 7-24. MOPAR IIIC EXHAUST EMISSION ANALYZER (BACK)

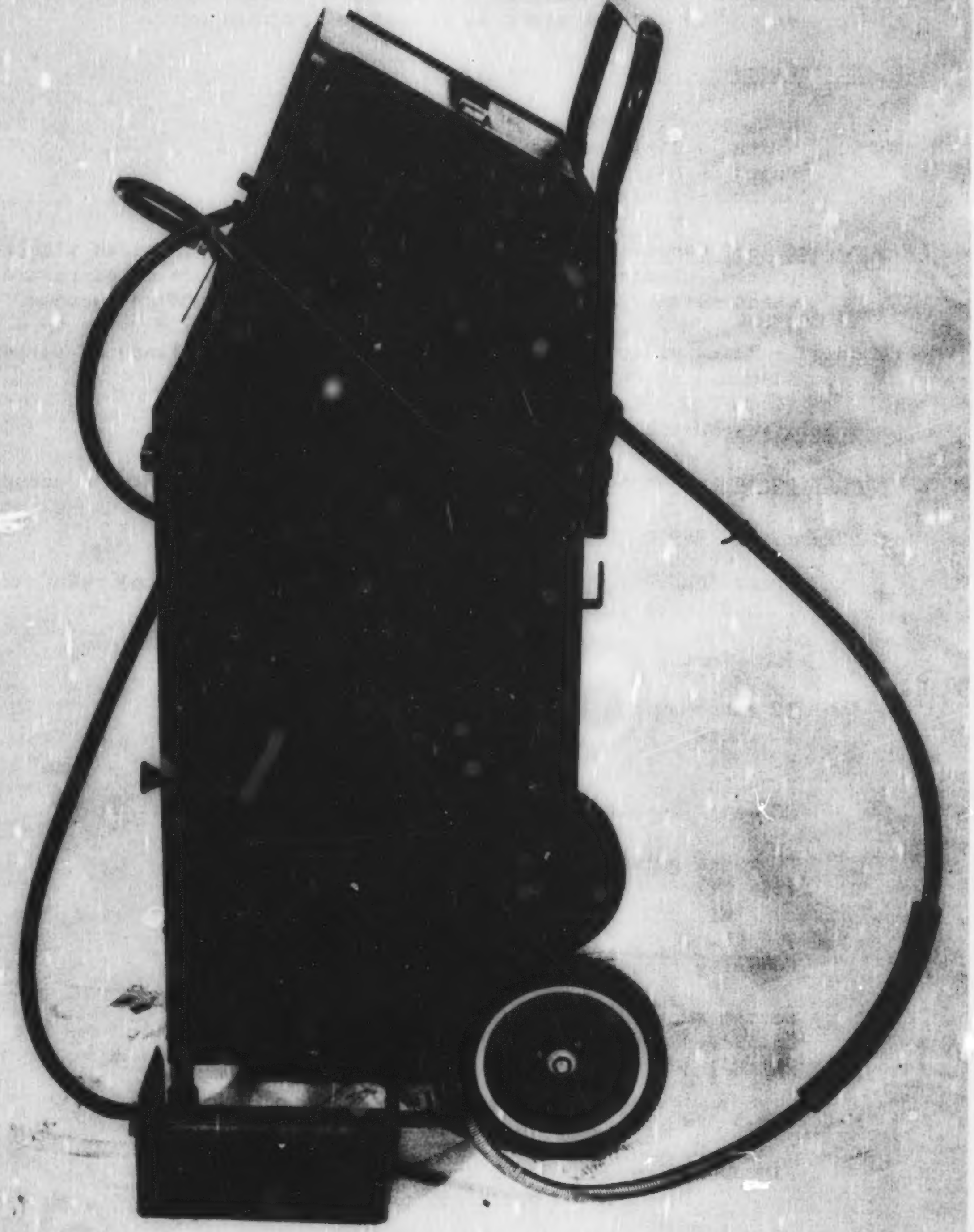

Figure 7-25. MOPAR IIIC EXHAUST EMISSION ANALYZER (LEFT SIDE AND PROBE)

7.9 SEARS 713.21022 HC-CO ANALYZER

Manufacturer - Emission Control Instruments Inc. (Sun Electric)

Description - HC/CO analyzer configured as a small portable bench top unit. No cart or stand is available for this unit.

Dimensions -

Height - 9 inches
Width - 15 inches
Depth - 6-1/2 inches
Weight - 10-1/4 lbs.

Material of Construction - Aluminum extrusion on top, molded plastic side panels, aluminum extrusion control panel, balance of parts are sheet metal. All parts jointed by grooves, slots and screws.

Color - Black sides, rear panels and meter frames; balance of parts are silver.

Mobility - Portable bench top unit.

Accessories - Sample probe, hose, filter material, operator's manual.

Control Package -

Front Access - Operation Mode switch (three-position)
1. Standby (with indicator light)
2. Run
3. Test

HC range switch (three-position)
1. Off
2. Hi
3. Lo
HC set - knob (zero)

CO range switch (three-position)
1. Off
2. Hi
3. Lo
CO set - knob (zero)

Bottom Access
Unlabeled - HC span - screw
Unlabeled - CO span - screw

Meters - 5-1/2", 100° swing

Ranges - HC - 0-2000 ppm in 50 ppm increments
0-500 ppm in 25 ppm increments

CO - 0-10% in 0.2% increments
0-2.5% in 0.1% increments
Air fuel ratio - 14.2-10.2 (on CO meter)

High ranges - Figures red on white background

Low ranges - Figures blue on white background

Meter visibility and readability is poor at moderate distance.

Altitude Compensation - None

Probe - Flowthrough T-shape constructed of spiral, flexible tube. The exhaust sample is pulled from the center of the probe. The majority of the exhaust sample passes through the probe and out the end.

Filters and Sample Handling - Glass fiber filter packed in a small plastic housing. No water trap. Small diameter sample house was soft but worked well.

Cal Gas Inlet - Sample hose used for calibration.

Power Requirements - 12 volts DC.

Operating Principles - Selective combustion utilizing vandia catalyst, charcoal stripper and dual thermocouples.

Calibration - Proper warm up indicated with HC range switch in off position and mode switch in test position. HC meter scale must be at blue set point (80 percent full scale) or above. No other calibration procedures are included in the operator's manual. Unlabeled factory span pots are accessible through bottom of instrument.

Operation and Calibration - Operation is simple but manual is somewhat confusing in its presentation.

Procedure -
1. Attach 12 V battery clips
2. Turn mode switch to standby
3. Check warm up
4. Set zero positions with switches in off position
5. Ready for use

7.9.1 Operational Performance Comments

In general, this instrument is not a precision measurement device nor is it advertised as such. It is an inexpensive instrument intended for home hobby use where relative test-to-test readings are the intended use. This unit is not intended to compete with other instruments in attempting to identify absolute sample gas values. This intended application explains the lack of calibration controls. Factory calibration is deemed adequate for this specific application.

This unit is designed to be primarily sensitive to exhaust gas components other than those characterized as hexane. Factory calibration utilizes a span gas composed of Butene-1 as the primary hydrocarbon and so its sensitivity to hexane or propane tends to differ dramatically from the typical sensitivity seen in other HC and CO analyzers.

The design of the sample probe was interesting in that it would tend to minimize the instrument's exposure to particulate accumulation. The sample probe was not used sufficiently to comment on its durability.

Instrument failure occurred repeatedly during testing but the following was determined. Warm up time appeared to be approximately 10 minutes. Zero drift of 5 percent full scale and 2 percent full scale were seen in cycle one tests of the HC and CO meters, respectively. The unit did not appear to be significantly sensitive to any of the interference gases.

In the accuracy tests, the HC meter showed essentially no response propane. Improper CO calibration resulted in the loss of cycle one CO accuracy data. Cycle four showed a maximum CO error on high scale of 3 percent and on low scale 10 percent.

Instrument response time was approximately 24 seconds. The hydrocarbon response pattern of the HC meter is apparent in the high altitude accuracy data, indicating very close correlation with benzene, but twice the anticipated isobutylene reading, and over three times the toluene reading. Methane response was slightly below the actual value. The unit showed no response to ethylene and minimal response to acetylene.

The unit experienced a sample pump failure during the laboratory test sequence. Due to problems encountered during attempts to replace the sample pump, a large number of laboratory tests were missed. Prior to the vehicle test phase, the instrument experienced a failure that rendered it inoperative. Attempts were made to notify the manufacturer of this failure but the manufacturer was involved in relocating operations to the east coast. The inability to secure repairs on this instrument caused the unit to miss most of the test cycles in the vehicle test and durability test phases.

Test data for Sears 713.21022 HC-CO Analyzer are shown in Tables 7-41 through 7-45

Photographs of the instrument are shown in Figures 7-26, 7-27, and 7-28.

Table 7-41. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: SEARS 713.21022

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	10	INSTRUMENT	MALFUNCTION	
	LOW	CO	10			

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	5.0	INSTRUMENT	MALFUNCTION	
	LOW	CO	2.0			

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	2.0	0	0	0
	LOW	CO	0	0	-	0	0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	INSTRUMENT NOT		INSTRUMENT NOT	
	HIGH	HC/CO	70	RESPONSIVE TO		CALIBRATED -	
	HIGH	HC/CO	100	PROPANE	-	INVALID	DATA
	LOW	HC/CO	35	NO	DATA		
	LOW	HC/CO	70				
	LOW	HC/CO	100				
CYCLE 2	HIGH	HC/CO	35	INSTRUMENT	FAILED	NO	DATA
	HIGH	HC/CO	70				
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				

Table 7-41. DATA COMPOSITE - LABORATORY TEST (Cont'd) Attachment (1)

SEARS 713.21022

CYCLE 3	HIGH	HC/CO	35		INSTRUMENT	FAILED	
	HIGH	HC/CO	70				
	HIGH	HC/CO	100		NO	DATA	
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				
CYCLE 4	HIGH	HC/CO	35		INSTRUMENT	FAILED	
	HIGH	HC/CO	70				
	HIGH	HC/CO	100		NO	DATA	
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				
HIGH ALTITUDE	HIGH	HC/CO	35	NOT SENSITIZED		+ 7.53	+ 2.8
	HIGH	HC/CO	70	FOR PROPANE		+ 4.62	+ 3.0
	HIGH	HC/CO	100	OR HEXANE		0	0
	LOW	HC/CO	35			+ 4.76	+ 2.0
	LOW	HC/CO	70			+ 9.71	+ 6.8
	LOW	HC/CO	100			+11.36	+10.0

				INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
	RANGE	SCALE	CORRECTED CONCENTRATION	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	3300ppm Propane	24.5	INSTRUMENT	"	"
	HIGH	CO	8.1	24.0	FAILED NO DATA	"	"

		INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
HYDROCARBON RESPONSE	RANGE	287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW		INSTRUMENT		MALFUNCTION		
6750 Feet Altitude	LOW	50	350	0	700	250	1100

Table 7-41. DATA COMPOSITE - LABORATORY TEST (Cont'd)

SEARS 713-21022

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	13.6V	HIGH	HC	INSTRUMENT	
	13.6V	HIGH	CO	MALFUNCTION	

Table 7-42. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: SEARS 713.21022

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
			INSTRUMENT MALFUNCTION			

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
			INSTRUMENT MALFUNCTION			

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
			INSTRUMENT MALFUNCTION					

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
			INSTRUMENT MALFUNCTION					

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
			INSTRUMENT MALFUNCTION					

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
			INSTRUMENT MALFUNCTION					

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
			INSTRUMENT MALFUNCTION				

Table 7-42. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1			INSTRUMENT MALFUNCTION				
CYCLE 2			INSTRUMENT MALFUNCTION				
CYCLE 3			INSTRUMENT MALFUNCTION				
CYCLE 4			INSTRUMENT MALFUNCTION				

Table 7-43. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

SEARS 713.21022

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
LEAN MODE CYCLE 1		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				

Table 7-43. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

SEARS 713.21022

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50		FAILED		
		HC/CO	30				
		HC/CO	IDLE				

Table 7-44. DIAGNOSTIC TEST

SEARS 713.21022

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED			INOPERATIVE			
NORMAL IDLE			INOPERATIVE			
IGNITION ADVANCE			INOPERATIVE			
IGNITION RETARD			INOPERATIVE			

Table 7-45. DURABILITY TEST DATA

INSTRUMENT: SEARS 713.21022

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	NO TEST DATA
TIME TO FAILURE (HRS.)	
HC EXPOSURE (PPM-HRS.)	
CO EXPOSURE (%-HRS.)	
NO EXPOSURE (PPM-HRS.)	
INSTRUMENT STABILITY	NO TEST DATA
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	
SHOCK TEST FAILURE RATE (Failure/Day %)	
INCIDENCE OF FAILURE IN EACH MODE	NO TEST DATA
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	NO TEST DATA
HC%	
CO%	
NO%	
INSTRUMENT SERVICE REQUIREMENTS	NO TEST DATA
A CHANGE FILTER TOTAL PER 100 HRS.	
B DRAIN HOSE TOTAL PER 100 HRS.	
C REZERO TOTAL PER 100 HRS.	
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	
E. OTHER TOTAL PER 100 HRS.	

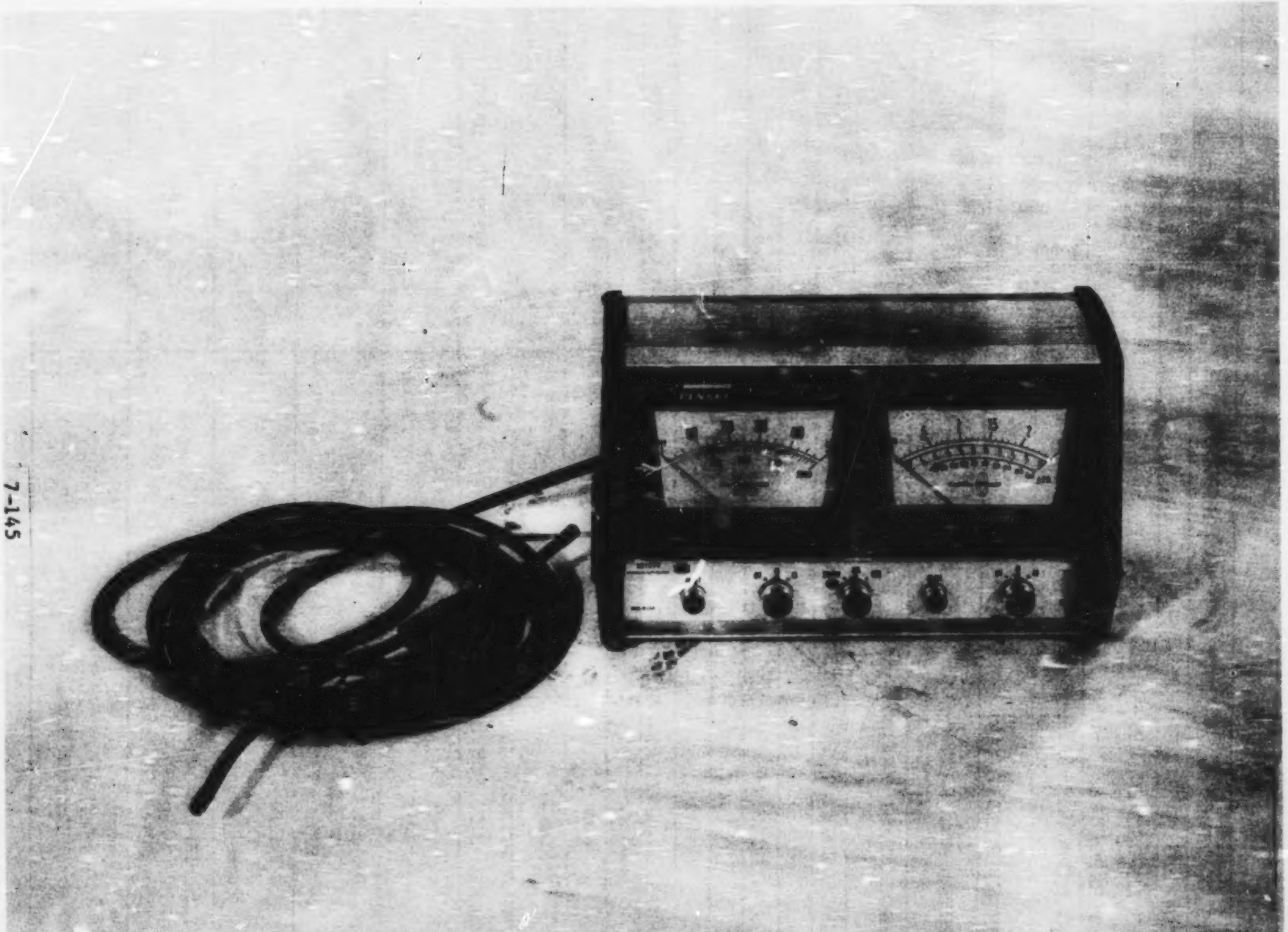

Figure 7-26. SEARS 713.21022 HC-CO ANALYZER

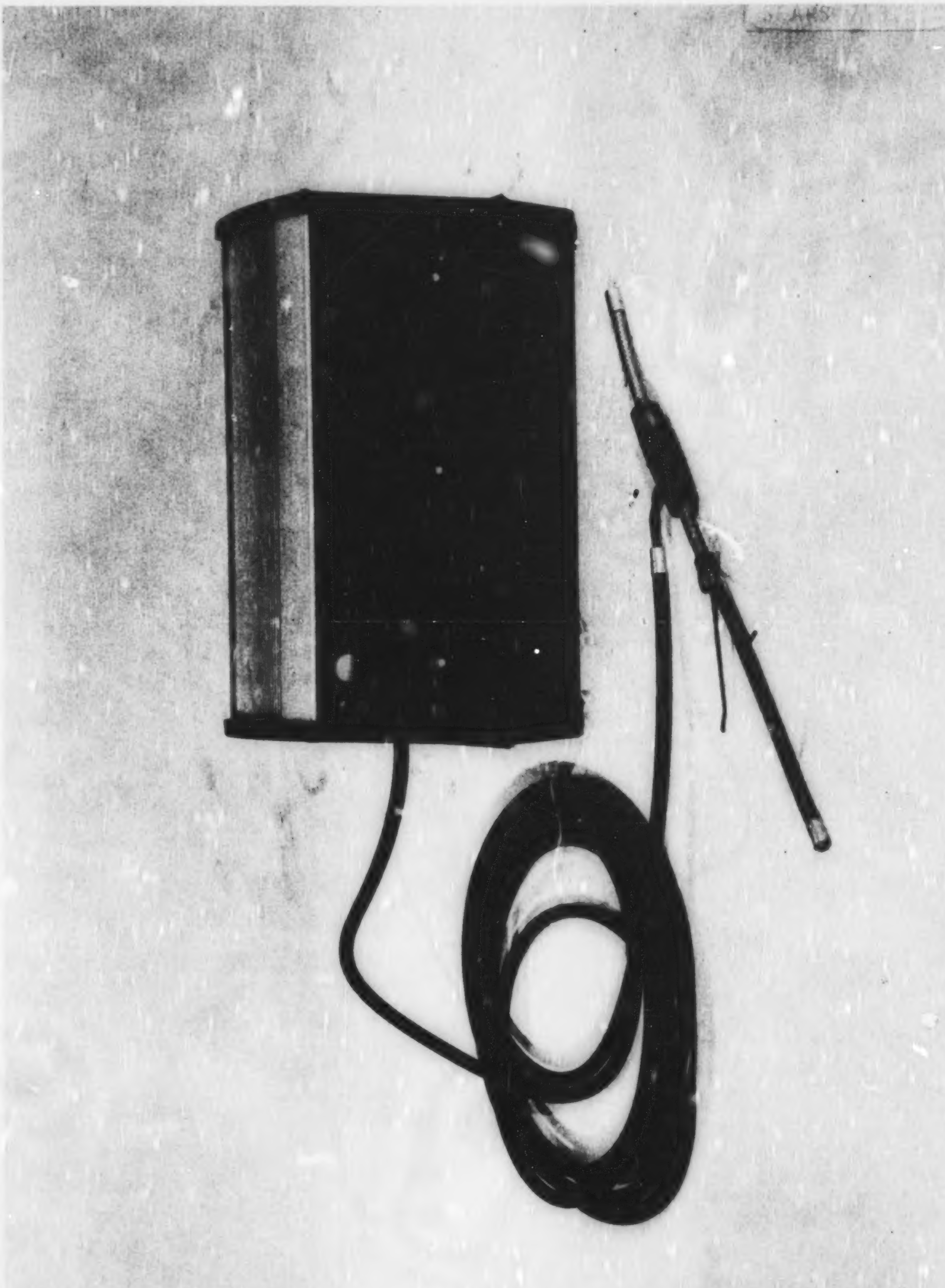

Figure 7-27. SEARS 713.21022 HC-CO ANALYZER (BACK AND PROBE)

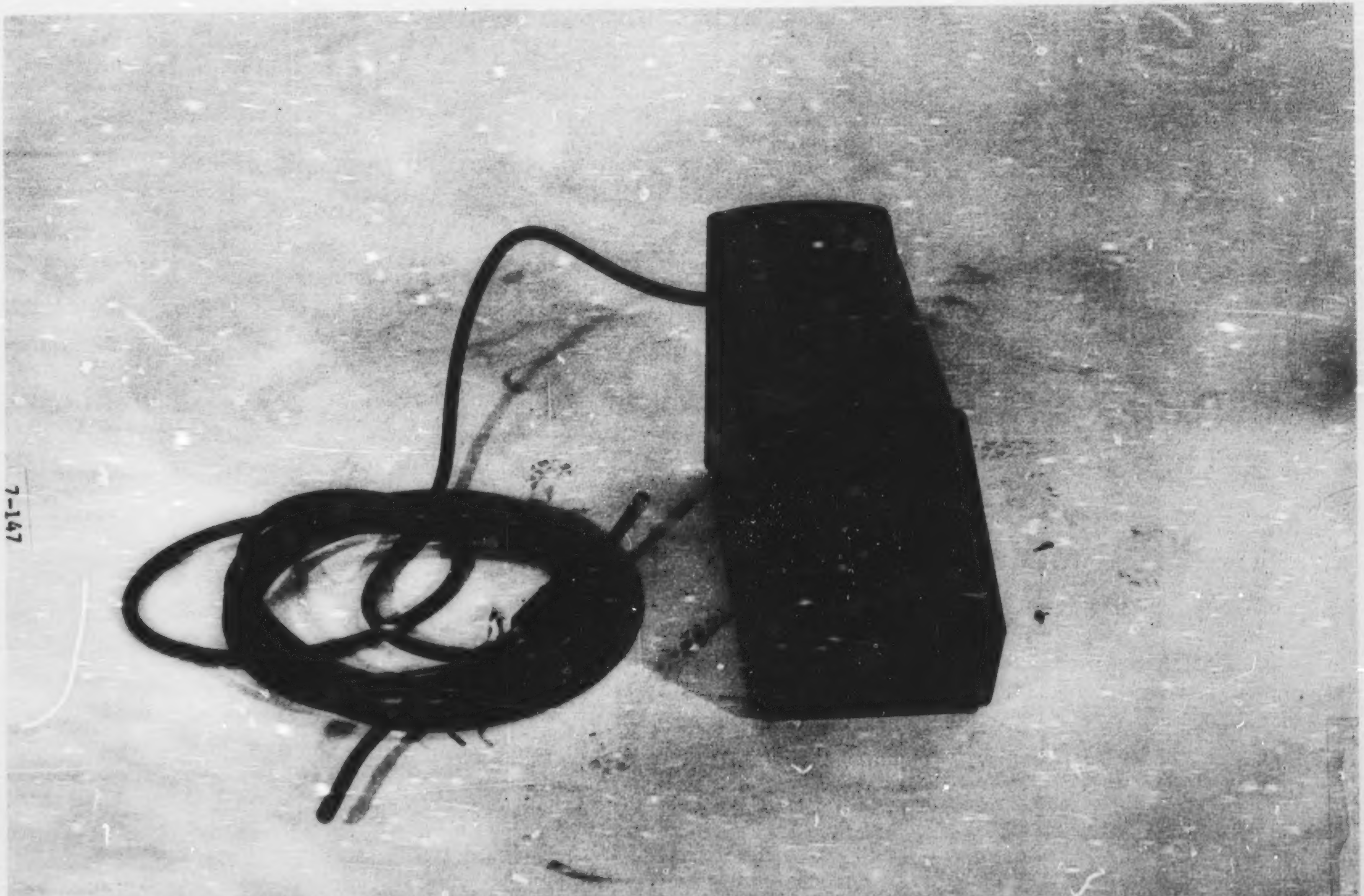

Figure 7-28. SEARS 713.21022 HC-CO ANALYZER (RIGHT SIDE AND PROBE)

7.10 KAL EQUIP 4094-D INFRARED EMISSIONS ANALYZER

Manufacturer - Kal Equip Company

Description - HC/CO analyzer configured as a bench top unit not supplied or available with wheels or cart. Molded plastic case has integral handle at top.

Description -

Height - 28-3/4 inches
Width - 11-1/4 inches
Depth - 15 inches
Weight - 18 lbs.

Material of Construction - Molded plastic housing.

Color - Grey with black trim.

Mobility - Portable.

Accessories - Sample probe, sample hose (20 feet) operator's manual, hexagonal span tool.

Control Package -

Front Access - Test selector (five-position)
1. Off
2. Zero
3. Span
4. High
5. Low
6. HC zero - knob
7. HC span - knob
8. HC 1 - Hexagonal pots
9. HC 2 - Hexagonal pots
10. HC 3 - Hexagonal pots
11. CO zero - knob
12. CO span - knob
13. CO 1 - Hexagonal pots
15. CO 3 - Hexagonal pots
16. Change filter - light
17. High HC - Hi CO - light (range)
18. Low HC - Lo CO - light (range)

Rear Access - Calibration valve (two-position)
1. Internal
2. External
3. Span gas inlet

Meters - Both meters on same face and unconventional in appearance, 6-inch, 100° swing. All figures black on white background.

Ranges - HC - 0-2000 ppm in 50 ppm increments
- 0-500 ppm in 10 ppm increments
CO - 0.10% in 0.2% increments
- 0.2.5% in 0.1% increments

These meters were insenstive to static electricity. Readability was fair at moderate distance. Range identification with lights was easy to distinguish.

Altitude Compensation - Included on chart in operator's manual. Used in conjunction with set points on meter faces. Not needed if gas calibrated at altitude of use.

Probe - The probe consisted of spiral flex tubing connected to a solid tube. Tail pipe spring and wooden handle were also included.

Filters and Sample Handling - Two filters, primary particulate type located in the sample probe, secondary particulate type located downstream of condensing tower, condensing tower (on instrument rear panel) used to remove sample moisture.

Cal Gas Inlet - Rear panel.

Power Requirements - 12 VDC 8.5 amps (no fuses or breakers).

Operating Principles - Single cell, rotating optical filters, chopper modulates infrared energy, and synchronizing windows in chopper wheel picks appropriate HC or CO circuit.

Calibration - Basically straightforward except that Lo and Hi scales have their own span adjustments resulting in four "span" related pots for each circuit. With function selector and numerous span pots, this unit is more complicated to calibrate than some other units.

Operation and Calibration - Operating instructions and calibration instructions were on stickers on the rear of the instrument. These rear panel stickers peeled loose during testing.

Operation -
1. Place "function selector" in zero position
2. Warm up
3. Zero
4. Calibrate - adjust to set marks
5. Ready for use
6. Optional gas calibration

7.10.1 Operational Performance Comments

The general control and display layout on this unit was moderately inconvenient. The operation and calibration of this instrument was complicated by the fact that the zero and span knobs were very close together and easy to confuse or bump. The infrared and electronics systems of the Kal Equip are very similar to those of the Stewart Warner. The meters were unconventional in appearance. They were small, and had nonlinear scales with poor resolution at the high end. The meters were built into one large module with the range/function switch. The meter needles rotated in opposite directions from the approximate center of this module, with the meter scales increasing in value from the bottom of the plate to the top. Range indicating lights were included on the meter face.

The hex socket adjustments, covered by rubber plugs and used for correlation of electronic span, were awkward to use. They were completely discussed in the instructions. Both the rubber plugs and the hex tool was easy to lose. In addition, the pots requiring this hex socket tool were deeply recessed in both this instrument and the Stewart Warner. It was sometimes very difficult to engage these pots during calibration. The sample handling equipment for the Kal Equip was very similar to that supplied with the Stewart Warner. However, there was no external bowl type water trap on the Kal Equip. This instrument had the sample hose connected inside the case. Sample hose service or replacement would require complete shutdown and case disassembly.

This unit demonstrated very slow nontypical response that seemed almost to step. Its stability was also relatively poor. The nomenclature internal/external used on the span gas control valve was somewhat confusing and did not clearly relate to its function.

This unit operated on 12 VDC power and was subject to the limitation of frequent on/off cycling by the user resulting in sufficient warm up, poor stability, accuracy and repeatability.

There was no over-voltage protection built into the instrument, thus a malfunctioning charging system in an automobile could damage internal components.

In the sampling system, the primary filter in the probe handle was relatively easy to change but the secondary filter near the cooling tower was very difficult and time-consuming to change due to its specific placement and securing method.

The maintenance required for this instrument was similar to that required on the Stewart Warner except that there was no maintenance requirements for the water trap. The in-line primary filter cartridge required changing more often.

In the laboratory tests this unit showed warm up times of 6 to 9 minutes except at cold temperatures, where it required 19 minutes.

Zero drift at normal laboratory temperatures and low temperature was 1.2 percent full scale or less. At high temperature, the HC drift climbed to 2.4 percent full scale but the CO drift was still only 0.8 percent full scale. Gas interference tests indicated CO meter sensitivity of up to 2 percent full scale to HC gas and CO senstivity of up to 2 percent full scale to NO gas. No other repeatable sensitivities were noted.

The Kal Equip was eleventh most accurate of all HC/CO instruments. Both low and high ranges of HC and CO showed significant error in analysis. High altitude operation actually showed an increase in both high scale HC and CO accuracy.

This phenomenon has not been totally explained by the balance of the data. In response and recovery, the unit consistently showed slow response time on the order of 25 seconds or greater.

The Kal Equip was not sensitive to acetylene, benzene or toluene and only marginally sensitive to ethylene and methane. It was most responsive to isobutylene. Voltage fluctuation caused very slight HC meter response but 1.0 percent full scale CO response for both plus and minus 10 percent voltage change.

In the vehicle tests the Kal Equip correlated eleventh best with the EPA bench. The unit demonstrated significant correlation problems, especially on the hydrocarbon scale.

This instrument failed during the repeatability test when the hydrocarbon scale could not be zeroed. The service Watsline, as specified in the operation's manual, was called several times daily for a period of 10 days; getting either a busy signal or no answer at all. The local service organization was contacted but seemed very reluctant to come out and service the instrument. They suggested laying the unit on its side and running air through it for a few hours. This procedure did not alleviate the problem. The service organization then insisted on verifying the warranty status with the factory before finally coming out and repairing the unit.

During the durability test the sample probe broke at the junction of the solid tube and the spiral flex tube. Later in the durability test, the filter light came on, indicating that a filter change was needed. Even though the filter was replaced the light stayed on for 5 to 10 minutes. This reoccurred numerous times. This unit completed 164 hours of durability testing. This represents 129,888 ppm-hours of HC exposure and 59 percent-hours of CO exposure. Prior to failure, the instrument demonstrated an average daily span drift of 7.9 percent full scale for HC and 11.14 percent full scale for CO. Final failure in the durability test resulted from the inability to zero the hydrocarbon scale, followed by the lack of response of the hydrocarbon scale to calibration gas.

Judging from our testing this unit needs much more zero adjustment range.

Test data for Kal Equip 4094-D Infrared Emissions Analyzer are shown in Tables 7-46 through 7-50.

Photographs of this instrument are shown in Figures 7-29, 7-30, and 7-31.

Table 7-46. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: KAL EQUIP 4094-D

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	7	9	19	6		
	LOW	CO	7	7	19	6		
ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	1.2	2.4	1.0	0		
	LOW	CO	0.8	0.8	0.4	0.4		
GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	1.0	0	0	0
	LOW	CO	6.0	0	-	0	2.0	0
ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO		
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS	
CYCLE 1	HIGH	HC/CO	35	- 4.18	- 1.55	+ 2.15	+ 0.8	
	HIGH	HC/CO	70	- 4.45	- 3.4	- 1.54	- 1.0	
	HIGH	HC/CO	100	- 0.05	- 0.05	0.0	0.0	
	LOW	HC/CO	35	+ 2.09	+ 0.8	0.0	0.0	
	LOW	HC/CO	70	+ 0.26	+ 0.2	- 3.43	- 2.4	
	LOW	HC/CO	100	- 5.17	- 4.8	- 9.09	- 8.0	
CYCLE 2	HIGH	HC/CO	35	- 5.53	- 2.05	+ 2.15	+ 0.8	
	HIGH	HC/CO	70	- 5.11	- 3.9	0.0	0.0	
	HIGH	HC/CO	100	- 0.05	- 0.05	+ 2.17	+ 2.0	
	LOW	HC/CO	35	- 8.38	- 3.2	+ 2.86	+ 1.2	
	LOW	HC/CO	70	- 1.79	- 1.4	- 2.86	- 2.0	
	LOW	HC/CO	100	+ 1.29	+ 1.2	- 6.82	- 6.0	

Table 7-46. DATA COMPOSITE - LABORATORY TEST (Cont'd) Attachment (1)

KAL EQUIP 4094-D

CYCLE 3	HIGH	HC/CO	35	- 4.18	- 1.55	+ 4.84	+ 1.8
	HIGH	HC/CO	70	- 5.11	- 3.9	- 3.08	- 2.0
	HIGH	HC/CO	100	- 0.31	- 0.3	- 2.17	- 2.0
	LOW	HC/CO	35	- 7.85	- 3.0	+ 4.76	+ 2.0
	LOW	HC/CO	70	- 0.77	- 0.6	- 2.86	- 2.0
	LOW	HC/CO	100	+ 1.29	+ 1.2	- 6.82	- 6.0
CYCLE 4	HIGH	HC/CO	35	- 5.53	- 2.05	+ 1.88	+ 0.7
	HIGH	HC/CO	70	- 5.11	- 3.9	+ 1.54	+ 1.0
	HIGH	HC/CO	100	0.0	0.0	- 1.09	- 1.0
	LOW	HC/CO	35	- 8.38	- 3.2	- 3.81	- 1.6
	LOW	HC/CO	70	- 0.51	- 0.4	- 7.43	- 5.2
	LOW	HC/CO	100	+ 2.37	+ 2.2	-11.36	-10.0
HIGH ALTITUDE	HIGH	HC/CO	35	-10.93	- 4.05	+ 0.81	+ 0.3
	HIGH	HC/CO	70	- 7.07	- 5.40	0	0
	HIGH	HC/CO	100	- 0.83	- 0.80	0	0
	LOW	HC/CO	35	-11.00	- 4.2	+ 4.76	+ 2.0
	LOW	HC/CO	70	- 3.06	- 2.4	- 5.71	- 4.0
	LOW	HC/CO	100	+ 0.22	+ 0.2	- 9.09	- 8.0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1848	26.5	31.0	36.5	38.5
	HIGH	CO	8.1	25.0	30.0	34.0	37.0

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	5	65	10	0
6750 Feet Altitude	LOW	0	0	10	70	15	11

Table 7-46. DATA COMPOSITE - LABORATORY TEST (Cont'd)

KAL EQUIP 4094-D

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	13.6V	HIGH	HC	0.15	0.20
	13.6V	HIGH	CO	1.0	1.0

Table 7-47. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: KAL EQUIP 4094-D

	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
WARMUP TIME (Min.)	LOW	HC	7	17	17	13
	LOW	CO	7	23	14	13

			MAXIMUM ZERO DRIFT % FULL SCALE			
	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	HC	1.0	4.4	3.0	MALFUNCTION
	LOW	CO	0.8	1.2	1.2	MALFUNCTION

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 1	LOW	HC	4.0	-	2.0	1.0	1.0	0
	LOW	CO	3.6	6.0	-	-	0.8	0.4

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 2	LOW	HC	0	-	1.0	0	0	0
	LOW	CO	0	0	-	0	2.0	0

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
GAS INTERFERENCE (% of FS) CYCLE 3	LOW	HC	0	-	1.0	0.4	0	0
	LOW	CO	3.2	0	-	0	0.8	0

	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2			
GAS INTERFERENCE (% of FS) CYCLE 4	LOW	HC	INSTRUMENT MALFUNCTION					
	LOW	CO	INSTRUMENT MALFUNCTION					

				INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
	RANGE	SCALE	CORRECTED CONCENTRATION	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1848	29	20	16	MALFUNCTION
	HIGH	CO	8.1	25	20.5	16.5	MALFUNCTION

Table 7-47. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

KAL EQUIP 4094-D

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	-5.86	-2.05	-0.54	-0.20
	HIGH	HC/CO	70	-5.11	-3.90	-3.08	-2.00
	HIGH	HC/CO	100	+0.21	+0.20	-2.17	-2.00
	LOW	HC/CO	35	-11.00	-4.20	+4.76	+2.00
	LOW	HC/CO	70	-8.16	-6.40	-1.71	-1.20
	LOW	HC/CO	100	-6.68	-6.20	-9.09	-8.00
CYCLE 2	HIGH	HC/CO	35	-5.53	-2.05	+10.22	+3.80
	HIGH	HC/CO	70	-6.74	-5.15	+3.08	+2.00
	HIGH	HC/CO	100	+1.25	+1.20	+2.17	+2.0
	LOW	HC/CO	35	-3.14	-1.20	+3.81	+1.60
	LOW	HC/CO	70	-0.51	-0.40	-1.14	-0.80
	LOW	HC/CO	100	-3.02	-2.80	-6.36	-5.60
CYCLE 3	HIGH	HC/CO	35	-0.13	-0.50	+6.18	+2.30
	HIGH	HC/CO	70	-0.52	-0.40	+4.62	+3.00
	HIGH	HC/CO	100	+2.28	+2.20	+6.52	+6.00
	LOW	HC/CO	35	-25.65	-9.80	+8.57	+3.60
	LOW	HC/CO	70	-3.57	-2.80	-5.14	-3.60
	LOW	HC/CO	100	-3.86	-3.60	-10.0	-8.80
CYCLE 4	HIGH	HC/CO	35				
	HIGH	HC/CO	70			INSTRUMENT MALFUNCTION	
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				

Table 7-48. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

KAL EQUIP 4094-D

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	500/2.5	HC/CO	50	- 48.51	- 13.88	+ 77.71	+ 19.24
	500/2.5	HC/CO	30	- 53. 6	- 16.28	+ 96.72	+ 4.72
	500/2.5	HC/CO	IDLE	- 58.36	- 33.64	+133.64	+ 34.32
CYCLE 2	500/2.5	HC/CO	50	- 63.34	- 17.28	+ 31.09	+ 6.64
	500/2.5	HC/CO	30	- 59.16	- 17.38	+ 2.56	+ 0.12
	500/2.5	HC/CO	IDLE	- 54.53	- 26.38	+ 48.51	+ 19.6
CYCLE 3	500/2.5	HC/CO	50	- 37.49	- 9.0	+ 31.8	+ 7.72
	500/2.5	HC/CO	30	- 36.80	- 9.9	+ 41.81	+ 2.36
	500/2.5	HC/CO	IDLE	- 44.54	- 20.88	+ 3.31	+ 1.6
CYCLE 4	500/2.5	HC/CO	50	- 26.95	- 6.64	+ 13.48	+ 3.8
	500/2.5	HC/CO	30	- 22.88	- 5.93	+ 30.43	+ 1.96
	500/2.5	HC/CO	IDLE	- 22.42	- 8.96	+ 21.50	+ 9.2
LEAN MODE CYCLE 1	500/2.5	HC/CO	50	- 50.46	- 15.28	+ 46.83	+ 12.12
	500/2.5	HC/CO	30	- 51.67	- 15.18	+ 90.84	+ 4.76
	500/2.5	HC/CO	IDLE	- 58.14	- 44.44	+ 30.49	+ 8.88
CYCLE 2	500/2.5	HC/CO	50	- 56.96	- 15.88	+ 40.85	+ 9.28
	500/2.5	HC/CO	30	- 59.57	- 17.68	+ 69.64	+ 3.12
	500/2.5	HC/CO	IDLE	- 64.88	- 44.34	+ 13.64	+ 2.88
CYCLE 3	500/2.5	HC/CO	50	- 31.45	- 8.26	+ 18.91	+ 6.68
	500/2.5	HC/CO	30	- 38.30	- 9.93	+ 45.04	+ 2.36
	500/2.5	HC/CO	IDLE	- 40.44	- 27.15	- 4.76	- 1.2
CYCLE 4	500/2.5	HC/CO	50	- 24.76	- 6.58	+ 13.82	+ 4.52
	500/2.5	HC/CO	30	- 24.99	- 6.00	+ 58.73	+ 2.96
	500/2.5	HC/CO	IDLE	- 27.78	- 16.15	+ 62.16	+ 9.2

Table 7-43. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

KAL EQUIP 4094-D

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	500/2.5	HC/CC	50	- 57.87	- 16.48	+ 49.81	+ 10.64
	500/2.5	HC/CO	30	- 60.76	- 18.58	- 4.76	- 0.4
	500/10	HC/CO	IDLE	- 51.23	- 42.02	- 15.18	- 5.6
CYCLE 2	500/2.5	HC/CO	50	- 57.08	- 23.94	+ 0.13	+ 0.04
	500/2.5	HC/CO	30	- 34.46	- 8.94	+ 27.40	+ 0.16
	500/10	HC/CO	IDLE	- 36.10	- 23.16	- 0.28	- 0.1
CYCLE 3	500/2.5	HC/CO	50	- 32.77	- 8.29	+ 10.95	+ 2.96
	500/2.5	HC/CO	30	- 42.16	- 10.93	+ 27.40	+ 0.16
	500/10	HC/CO	IDLE	- 54.46	- 33.48	- 16.92	- 5.5
CYCLE 4	500/2.5	HC/CO	50	- 22.88	- 5.93	+ 13.48	+ 3.8
	500/2.5	HC/CO	30	- 29.71	- 7.61	+ 32.35	+ 1.76
	500/10	HC/CO	IDLE	- 34.38	- 21.48	+ 2.84	+ 0.91

Table 7-49. DIAGNOSTIC TEST

KAL EQUIP 4094-D

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	500	HC	340	406.15	- 16.29	- 13.23
	2.5	CO	1.10	1.955	- 43.73	- 34.2
NORMAL IDLE	500	HC	190	217.89	- 12.80	- 5.58
	2.5%	CO	1.20	2.223	- 46.02	- 40.92
IGNITION ADVANCE	500	HC	175	134.53	+ 30.08	+ 16.19
	2.5%	CO	1.15	1.864	- 38.30	- 28.56
IGNITION RETARD	500	HC	150	131.29	+ 14.25	+ 3.74
	2.5%	CO	1.0	1.934	- 48.29	- 37.36

Table 7-50. DURABILITY TEST DATA

INSTRUMENT: KAL EQUIP 4094-D

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	164
HC EXPOSURE (PPM-HRS.)	129,888
CO EXPOSURE (%-HRS.)	59
NO EXPOSURE (PPM-HRS.)	16,236
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	NOT APPLICABLE
SHOCK TEST FAILURE RATE (Failure/Day %)	NOT APPLICABLE
INCIDENCE OF FAILURE IN EACH MODE	NOT APPLICABLE
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	
HC%	7.9
CO%	11.14
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	13
PER 100 HRS.	7.98
B DRAIN HOSE	
TOTAL	--
PER 100 HRS. .	--
C REZERO	
TOTAL	1
PER 100 HRS.	0.61
D. SAMPLING SYSTEM	
TOTAL	2
PER 100 HRS.	1.22
E. OTHER	
TOTAL	3
PER 100 HRS.	1.83

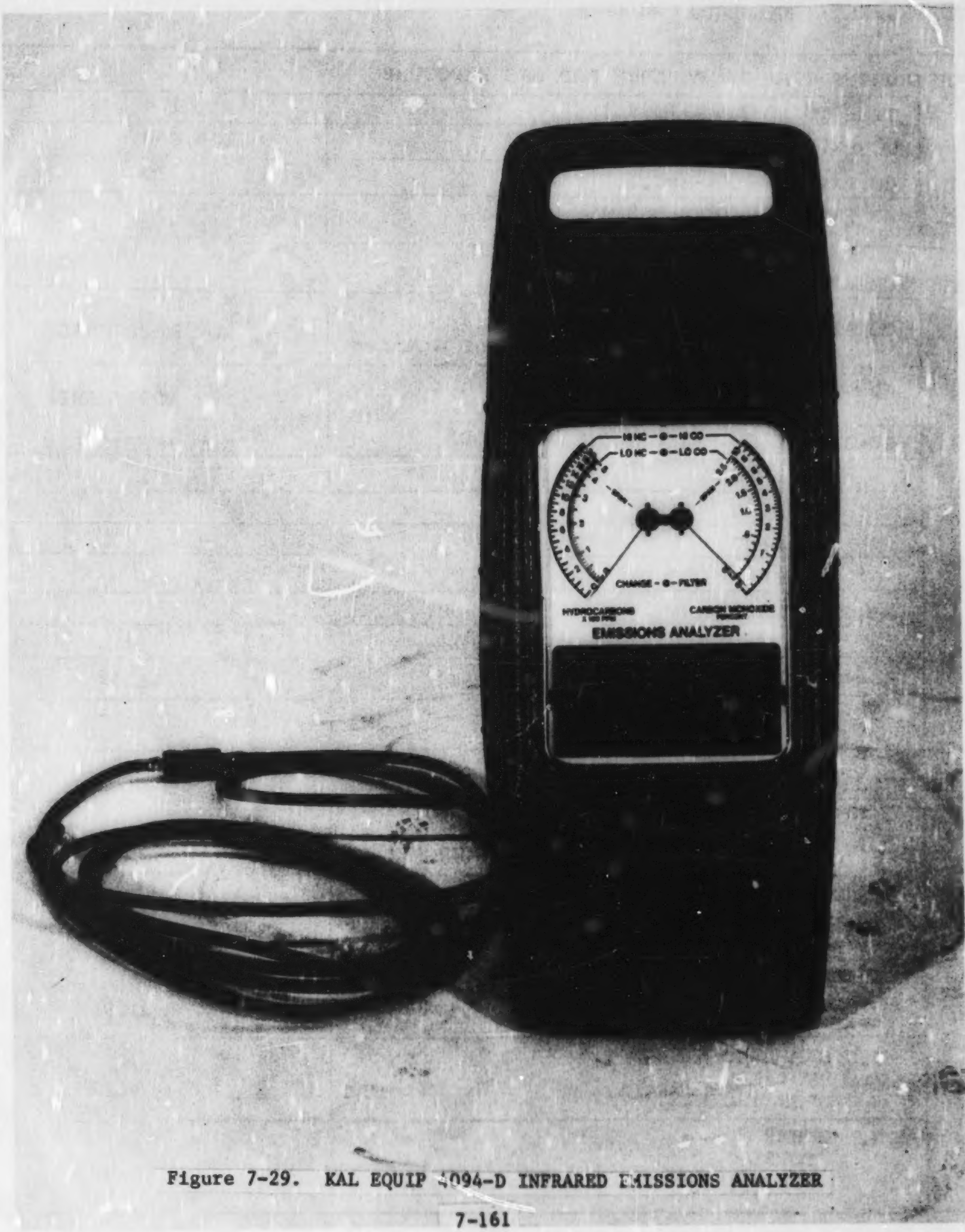
HI HC — ● — HI CO
LO HC — ● — LO CO
CHANGE — ● — FILTER
HYDROCARBONS
CARBON MONOXIDE
EMISSIONS ANALYZER

Figure 7-29. KAL EQUIP 4094-D INFRARED EMISSIONS ANALYZER

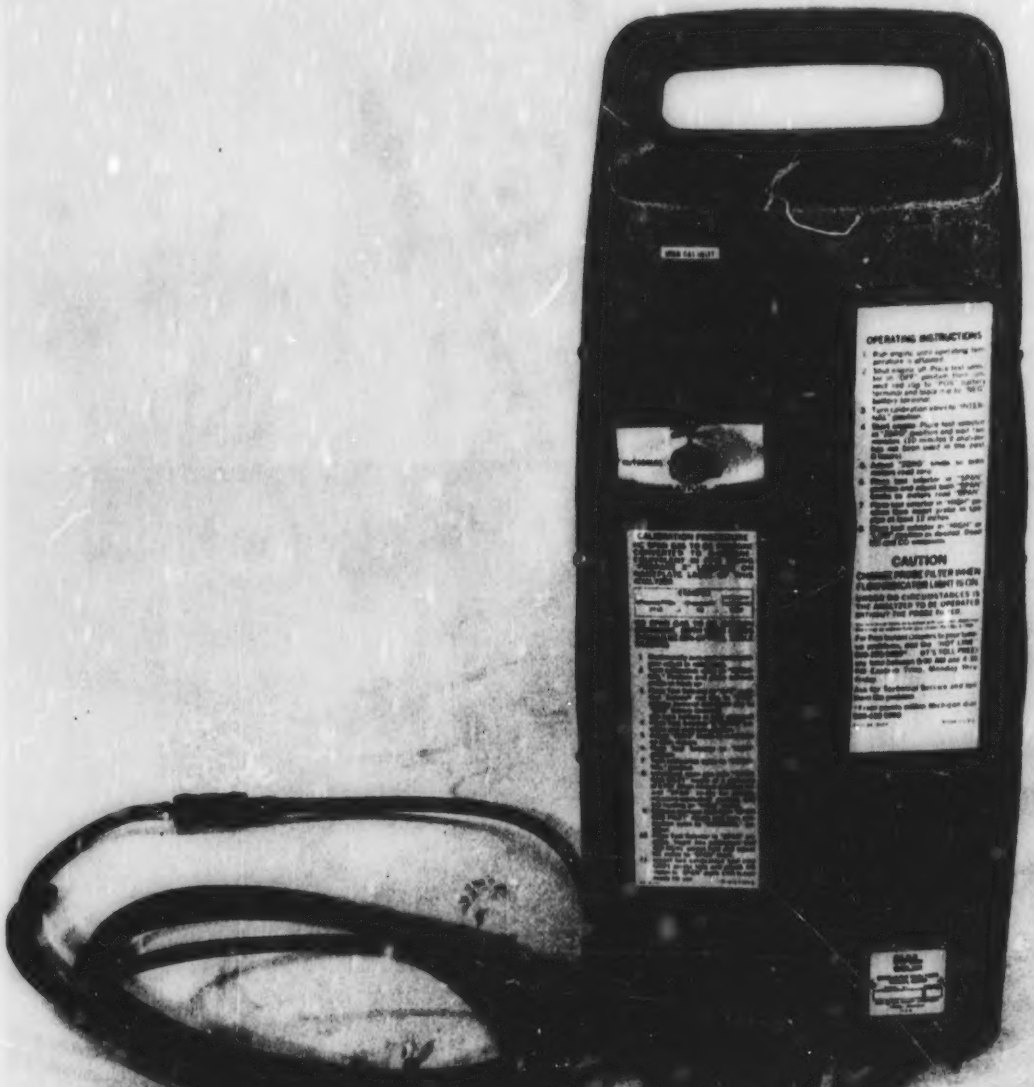

Figure 7-30. KAL EQUIP 4094-D INFRARED EMISSIONS ANALYZER (BACK AND PROBE)

Figure 7-31. KAL EQUIP 4094-D INFRARED EMISSIONS ANALYZER (LEFT SIDE)

7.11 PULSAR 662 INFRARED ANALYZER

Manufacturer - Peerless Instrument Company

Description - HC/CO exhaust analyzer configured as separate, bench top sample handling/analysis and readout/control modules fitted to a compartmentalized two-wheel cart. The modules can be used without the cart.

Dimensions -

Height - 13 inches
Width - 8-5/8 inches
Depth - 14-1/2 inches

Readout/Control Module
Height - 12-1/2 inches
Width - 8-5/8 inches
Depth - 7-1/2 inches

Cart -
Height - 36-1/4 inches
Width - 20-1/2 inches
Depth - 18-3/4 inches

Material of Construction - Sheet metal, joined by welding and screws .

Color - Cart is gold with black trim, modules are black with gold trim.

Mobility - Two, rear-mounted, 8-inch diameter wheels, front sheet metal legs. Handle is mounted at top rear of unit. Mobility is good with well placed C.G.

Accessories - Sample probe, sample hose, module interconnect cable, operator's manual, chain-connected to cart for instructions.

Control Package - All functions in both modules are controlled from the readout/control module.

Front Access - Mode control (four push buttons)

1. Standby
2. Calibration zero
3. Calibration span
4. Test
5. Main power - toggle on/off
6. Flow blocked - indicator light
7. HC span - knob
8. HC zero - knob
9. Range - toggle - high/low
10. CO span - knob
11. CO zero - knob
12. Range - toggle - high/low
13. 15 amp breaker

Meters - 5-1/2", 90^{o} sweep
Black characters on white background
Red bar for high scales
Gold bar for low scales
Span marks on meter faces
Air fuel ratio markings on CO meter face (14.7 to 10.5 afr).

Ranges - HC - 0-2000 ppm in 50 ppm increments
0-400 ppm in 10 ppm increments
CO - 0-10% in 0.20% increments
0-2% in 0.05% increments

Meters were not sensitive to static electricity.

Altitude Compensation - Chart in operator's manual used during electronic calibration. Not needed when gas calibration used at test site.

Probe - Flexible braided metallic hose connected to rigid tubing. Handle and tail pipe clamp are one piece. Metallic screen in probe tip.

Filters and Sample Handling - Primary metallic screen in probe tip acts as course particulate filter. A water trap is located immediately upstream of the entrance to sample module. Water trap also incorporates a 100 mesh stainless steel filter element.

Cal Gas Inlet - Injection port on top of water trap.

Power Requirements - 12 volt DC 9.5 amps

Operating Principles - Dual cell nondispersive infrared, dual hot wire source dual detector (thermopile) chopper blade, band pass optical filters.

Calibration - Straightforward - both electronic and span gas calibration uses same span pots. No external ability to set individual ranges or adjust inter-range correlation.

Operation and Calibration - Fairly straightforward but complicated by operating mode push buttons.

Operation -
1. Connect 12 volt power clips
2. Warm up with main power on and standby button pushed
3. Electronic zero and span set
4. Ready for use (push test button)
5. Optional gas calibration

7.11.1 Operational Performance Comments

The mechanical package for this unit consisted of an electronic module and a sample processing module, connected by an electrical cable. Both of the modules fit into a cabinet equipped with two wheels and two stationary feet. The cabinet had a vertical storage space with one hangar inside of the hose and power cord. This storage area had a hinged door on the front.

The sampling system utilized a braided probe. During the test sequences no fraying of this probe was noted, but the metallic screen in the tip of the probe disintegrated. The sample hose was short and made of soft, large diameter rubber tubing. During durability testing, this hose continually filled with water. The hose was attached by a slip-on tubular connector. Its integrity is questionable. The water trap contained a series of screens acting as a particulate filter.

The unit was interesting from a design standpoint, due to its modular separation of the sample handling and analysis function from the control and readout function.

In use, the sample handling and analyzing module was located near the rear of the test vehicle, while the control and readout module was located near the front. Interconnection was achieved through the use of a multiconductor electrical cable. There appeared to be no clear advantage in function separation except reduction in sample transit time (response time). In reality, this separation merely added one more piece of equipment to be moved and positioned. Due to the short sample hose length, the modules could not effectively be used for "underhood" work while installed in the cart.

The infrared section of the Pulsar uses two tubes which are spilt horizontally, with the lower section for the sample and the upper section for reference. It was noted that this instrument had nontypical response characteristics. The unit appeared to be very unstable; the readings exhibiting continual up and down drift. It was noted that both the HC and CO meters "slipped" when the cycling fan came on in the sample module.

The Pulsar had the lowest meter height (above floor level when in cart) of all the console-type instruments tested. In addition to the standard CO meter scales, an air/fuel ratio scale was inscribed on the CO meter. The correct CO range selection for use with this air/fuel ratio scale was not specified on the instrument.

The zero and span knobs were very close together on the instrument face. They were easy to mistake or bump. The power switch was easy to mistake for the HC range switch.

Calibration gas input required fitting a hose adaptor to the calibration port. The calibration port was located at the bottom front of the sample handling module on top of the water traps.

Operating instructions for the instrument were on a plastic card attached by a chain to the stand. The calibration instructions on the back of the card was judged to be incomplete.

In the laboratory tests, this unit showed warm up times of 12 minutes or less, except at low temperatures, where 20 minutes were required.

Zero drift was typically 2.5 percent full scale or less with the exception of high temperature tests. Zero drift climbed to 10 percent full scale for HC and 5 percent full scale for CO indicating sensitivity to high temperatures.

Gas interference tests indicated slightly more than 1 percent full scale repeatable HC response to CO. In addition, the CO meter showed 0.8 percent to 2.0 percent full scale response to NO.

In accuracy determination, the Pulsar was rated ninth overall with no clear pattern of weakness. High altitude tests showed slightly better accuracy overall. The response time of this instrument was very consistent for HC and only slightly less consistent for CO. Times varied between 12 and 18 seconds.

The Pulsar was not sensitive to acetylene, benzene or ethylene and only marginally sensitive to methane. It was most sensitive to isobutylene, follwed by toluene. Voltage fluctuation caused essentially no meter response. During the repeatability tests, cycle four, the HC meter refused to zero. Operation on air for 3 hours caused the meter to resume normal operation. The problem was never diagnosed.

In the vehicle test, the Pulsar correlated eighth best overall with the EPA instrument. Generally, the HC scale showed significantly more error than the CO scale.

In the durability tests, the Pulsar completed 309 hours of operation. This corresponds to 288,297 ppm-hours of HC exposure and 454 percent-hours of CO exposure.

The unit was moderately sensitive to shock and vibration; experiencing 7 days of testing when the shock test caused more than 3 percent full scale meter variation.

This unit showed significant average daily span drift on the order of 16.3 percent full scale and 9.9 percent full scale for CO. The particulate filter required cleaning 13 times during the durability tests.

In the area of maintenance, the sample hose continually filled with water, blocking the sample flow. The sample hose required very frequent draining during durability testing. During the vibration test on this instrument, the axle retaining cap fell off, allowing one of the wheels to slip off the end of the axle. In the durability test, failure resulted when the HC meter could not be rezeroed with an air input.

Test data for Pulsar 662 Infrared Analyzer are shown in Tables 7-51 through 7-55.

Photographs of this instrument are shown in Figures 7-32, 7-33, and 7-34.

Table 7-51. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: PULSAR 662

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	12	10	20	6
	LOW	CO	9	8	20	6

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	2.5	10.0	2.5	1.25
	LOW	CO	2.5	5.0	1.0	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0.01	0	0	0
	LOW	CO	0.5	0	-	0	1.0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC % ERROR ABSOLUTE	HC % ERROR FS	CO % ERROR ABSOLUTE	CO % ERROR FS
CYCLE 1	HIGH	HC/CO	35	- 7.56	- 2.25	+ 2.15	+ 0.8
	HIGH	HC/CO	70	- 8.39	- 5.15	+ 4.62	+ 3.0
	HIGH	HC/CO	100	+ 5.69	+ 4.4	+ 1.09	+ 1.0
	LOW	HC/CO	35	- 1.1	- 0.25	+15.94	+ 5.5
	LOW	HC/CO	70	- 1.42	- 0.75	0.0	0.0
	LOW	HC/CO	100	- 1.59	- 1.25	+ 2.86	+ 2.5
CYCLE 2	HIGH	HC/CO	35	- 2.52	- 0.75	- 3.23	- 1.2
	HIGH	HC/CO	70	- 3.5	- 2.15	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 1.49	- 1.15	+ 1.09	+ 1.0
	LOW	HC/CO	35	-16.48	- 3.75	+ 8.7	+ 3.0
	LOW	HC/CO	70	-10.38	- 5.5	- 0.95	- 0.5
	LOW	HC/CO	100	- 6.35	- 5.0	0.0	0.0

Table 7-51. DATA COMPOSITE - LABORATORY TEST (Cont'd)

PULSAR 662

CYCLE 3	HIGH	HC/CO	35	- 2.52	- 0.75	- 3.23	- 1.2
	HIGH	HC/CO	70	- 4.72	- 2.9	+ 2.31	+ 1.5
	HIGH	HC/CO	100	- 2.46	- 1.9	+ 2.17	+ 2.0
	LOW	HC/CO	35	0.0	0.0	+ 8.7	+ 3.0
	LOW	HC/CO	70	- 3.3	- 1.75	- 0.95	- 0.5
	LOW	HC/CO	100	0.0	0.0	+ 2.29	+ 2.0
CYCLE 4	HIGH	HC/CO	35	- 0.84	- 0.25	- 3.25	- 1.2
	HIGH	HC/CO	70	- 3.1	- 1.9	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.52	- 0.4	+ 1.09	+ 1.0
	LOW	HC/CO	35	+10.99	+ 2.5	+10.15	+ 3.5
	LOW	HC/CO	70	- 2.52	- 0.75	- 3.23	- 1.2
	LOW	HC/CO	100	- 1.27	- 1.0	+ 4.0	+ 3.5
HIGH ALTITUDE	HIGH	HC/CO	35	- 0.84	- 0.25	- 5.91	- 2.2
	HIGH	HC/CO	70	+ 9.94	+ 6.1	- 3.08	- 2.0
	HIGH	HC/CO	100	- 1.16	- 0.90	- 2.17	- 2.0
	LOW	HC/CO	35	- 2.20	- 0.50	+ 8.70	+ 3.0
	LOW	HC/CO	70	- 5.66	- 3.0	- 0.95	- 0.5
	LOW	HC/CO	100	- 1.59	- 1.25	+ 1.71	+ 1.5

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1485	16.5	18.5	16.25	16.0
	HIGH	CO	8.1	16.5	15.5	12.0	12.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	0	51	8	21
6750 Feet Altitude	LOW	0	0	5	60	7	29

Table 7-51. DATA COMPOSITE - LABORATORY TEST (Cont'd)

PULSAR 662

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	13.6V	HIGH	HC	0	0.25
	13.6V	HIGH	CO	0.50	0

Table 7-52. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **PULSAR 662**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	10	22	19	15
	LOW	CO	11	17	17	13

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	5.0	3.75	1.5	0.75
	LOW	CO	1.0	0.5	1.0	0.50

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0.5	-	1.25	0	0.5	0
	LOW	CO	1.0	0.5	-	0	1.0	1.0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	1.5	-	1.25	0	0	0
	LOW	CO	0.5	0	-	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0.75	1.25	0	0
	LOW	CO	1.0	0	-	0.5	0	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0	0.5	0	0
	LOW	CO	1.5	0	-	0	0	0

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1485	21	15	9.5	9
	HIGH	HC	8.1	21.5	15	9	6.5

Table 7-52. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

PULSAR 662

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	-0.84	-0.25	+1.88	+0.70
	HIGH	HC/CO	70	-3.10	-1.90	+3.85	+2.50
	HIGH	HC/CO	100	-1.49	-1.15	+1.09	+1.00
	LOW	HC/CO	35	-1.10	-0.25	+10.15	+3.50
	LOW	HC/CO	70	-1.89	-1.00	-1.91	-1.00
	LOW	HC/CO	100	-0.95	-0.75	0	0
CYCLE 2	HIGH	HC/CO	35	-6.72	-2.0	+0.81	+0.30
	HIGH	HC/CO	70	-6.43	-3.95	+1.54	+1.00
	HIGH	HC/CO	100	-8.91	-6.90	+3.26	+3.0
	LOW	HC/CO	35	0	0	+13.04	+4.50
	LOW	HC/CO	70	-0.95	-0.50	+2.86	+1.54
	LOW	HC/CO	100	+0.95	+0.75	+3.43	+3.0
CYCLE 3	HIGH	HC/CO	35	+3.36	+1.00	-3.23	-1.2
	HIGH	HC/CO	70	-1.47	-0.9	0	0
	HIGH	HC/CO	100	-1.81	-1.40	+7.61	+7.00
	LOW	HC/CO	35	0	0	+10.14	+3.5
	LOW	HC/CO	70	-5.19	-2.75	0	0
	LOW	HC/CO	100	+0.95	+0.75	+0.57	+0.50
CYCLE 4	HIGH	HC/CO	35	+4.37	+1.30	+2.15	+0.80
	HIGH	HC/CO	70	-3.91	-2.40	+10.77	+7.0
	HIGH	HC/CO	100	-1.81	-1.40	-6.52	-6.0
	LOW	HC/CO	35	-9.87	-2.25	+1.45	+0.50
	LOW	HC/CO	70	-0.94	-0.50	-4.76	-2.50
	LOW	HC/CO	100	+1.59	+1.25	-2.86	-2.50

Table 7-53. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

PULSAR 662

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	400/2	HC/CO	50	- 29.78	- 10.6	- 10.1	- 3.65
	400/2	HC/CO	30	- 31.33	- 11.98	- 36.51	- 2.3
	400/2	HC/CO	IDLE	- 26.69	- 18.2	+ 22.22	+ 10.0
CYCLE 2	400/2	HC/CO	50	- 41.99	- 14.48	+ 7.14	+ 2.0
	400/2	HC/CO	30	- 36.8	- 13.1	- 24.11	- 1.35
	400/2	HC/CO	IDLE	- 38.2	- 24.73	+ 26.26	+ 13.0
CYCLE 3	400/2	HC/CO	50	- 34.6	- 9.13	- 21.05	- 8.0
	400/2	HC/CO	30	- 27.21	- 7.48	+ 47.54	+ 2.9
	400/2	HC/CO	IDLE	- 29.94	- 16.03	- 1.63	- 1.0
CYCLE 4	400/2	HC/CO	50	- 26.07	- 6.88	- 17.94	- 7.65
	400/2	HC/CO	30	- 23.36	- 6.25	- 33.77	- 2.55
	400/2	HC/CO	IDLE	- 18.47	- 9.18	- 3.85	- 2.0
LEAN MODE CYCLE 1	400/2	HC/CO	50	- 34.65	- 12.73	- 13.04	- 4.5
	400/2	HC/CO	30	- 31.91	- 11.6	- 40.17	- 2.35
	400/2	HC/CO	IDLE	- 20.95	- 15.9	+ 0.67	+ 0.2
CYCLE 2	400/2	HC/CO	50	- 43.82	- 15.6	- 18.43	- 5.65
	400/2	HC/CO	30	- 38.63	- 14.48	+ 68.22	+ 3.65
	400/2	HC/CO	IDLE	- 21.35	- 16.29	+ 1.9	+ 0.55
CYCLE 3	400/2	HC/CO	50	- 27.22	- 8.6	- 1.93	- 0.85
	400/2	HC/CO	30	- 25.81	- 8.26	+ 34.75	+ 2.45
	400/2	HC/CO	IDLE	- 29.15	25.2	- 12.88	- 3.4
CYCLE 4	400/2	HC/CO	50	- 39.07	- 12.83	- 4.19	- 1.75
	400/2	HC/CO	30	- 33.28	- 9.85	- 43.26	- 3.05
	400/2	HC/CO	IDLE	- 30.81	- 25.6	+ 17.85	- 2.65

Table 7-53. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

PULSAR 662

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	400/2	HC/CO	50	- 34.74	- 11.98	- 2.14	- 0.6
	400/2	HC/CO	30	- 41.22	- 15.6	- 55.0	- 5.5
	2000/10	HC/CO	IDLE	- 42.5	- 8.69	+ 5.34	+ 1.9
CYCLE 2	400/2	HC/CO	50	- 27.22	- 8.6	- 2.44	- 1.0
	400/2	HC/CO	30	- 28.8	- 9.1	- 36.17	- 2.55
	400/10	HC/CO	IDLE	- 29.65	- 24.03	+ 6.51	+ 2.2
CYCLE 3	400/2	HC/CO	50	- 41.22	- 15.6	+ 4.65	+ 1.6
	400/2	HC/CO	30	- 30.61	- 9.93	- 31.51	- 2.3
	400/10	HC/CO	IDLE	- 23.1	- 17.38	+ 5.74	+ 1.9
CYCLE 4	400/2	HC/CO	50	- 38.29	- 12.1	- 3.85	- 1.3
	400/2	HC/CO	30	- 28.01	- 8.85	+ 27.66	+ 19.5
	400/10	HC/CO	IDLE	- 25.33	- 19.68	+ 5.43	+ 1.7

Table 7-54. DIAGNOSTIC TEST

PULSAR 662

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	400	HC	240	401.1	- 40.16	- 40.28
	10%	CO	2.20	1.97	- 11.68	- 2.3
NORMAL IDLE	400	HC	116	231.1	- 49.81	- 28.78
	10%	CO	2.60	1.90	- 36.84	- 7.0
IGNITION ADVANCE	400	HC	100	147.5	- 32.2	- 11.88
	10%	CO	2.40	2.03	- 18.23	- 3.7
IGNITION RETARD	400	HC	97	134.5	- 27.88	- 9.38
	10%	CO	2.70	2.06	- 31.07	- 6.4

Table 7-55. DURABILITY TEST DATA

INSTRUMENT: PULSAR 662

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	309
HC EXPOSURE (PPM-HRS.)	288,297
CO EXPOSURE (%-HRS.)	454
NO EXPOSURE (PPM-HRS.)	32,136
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	7
SHOCK TEST FAILURE RATE (Failure/Day %)	35.0
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	1
HC SPAN	5
CO ZERO	0
CO SPAN	1
AVERAGE DAILY SPAN DRIFT	
HC%	16.28
CO%	9.86
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	--
PER 100 HRS.	--
B DRAIN HOSE	
TOTAL	60
PER 100 HRS.	19.42
C REZERO	
TOTAL	--
PER 100 HRS.	--
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	1
PER 100 HRS.	0.32

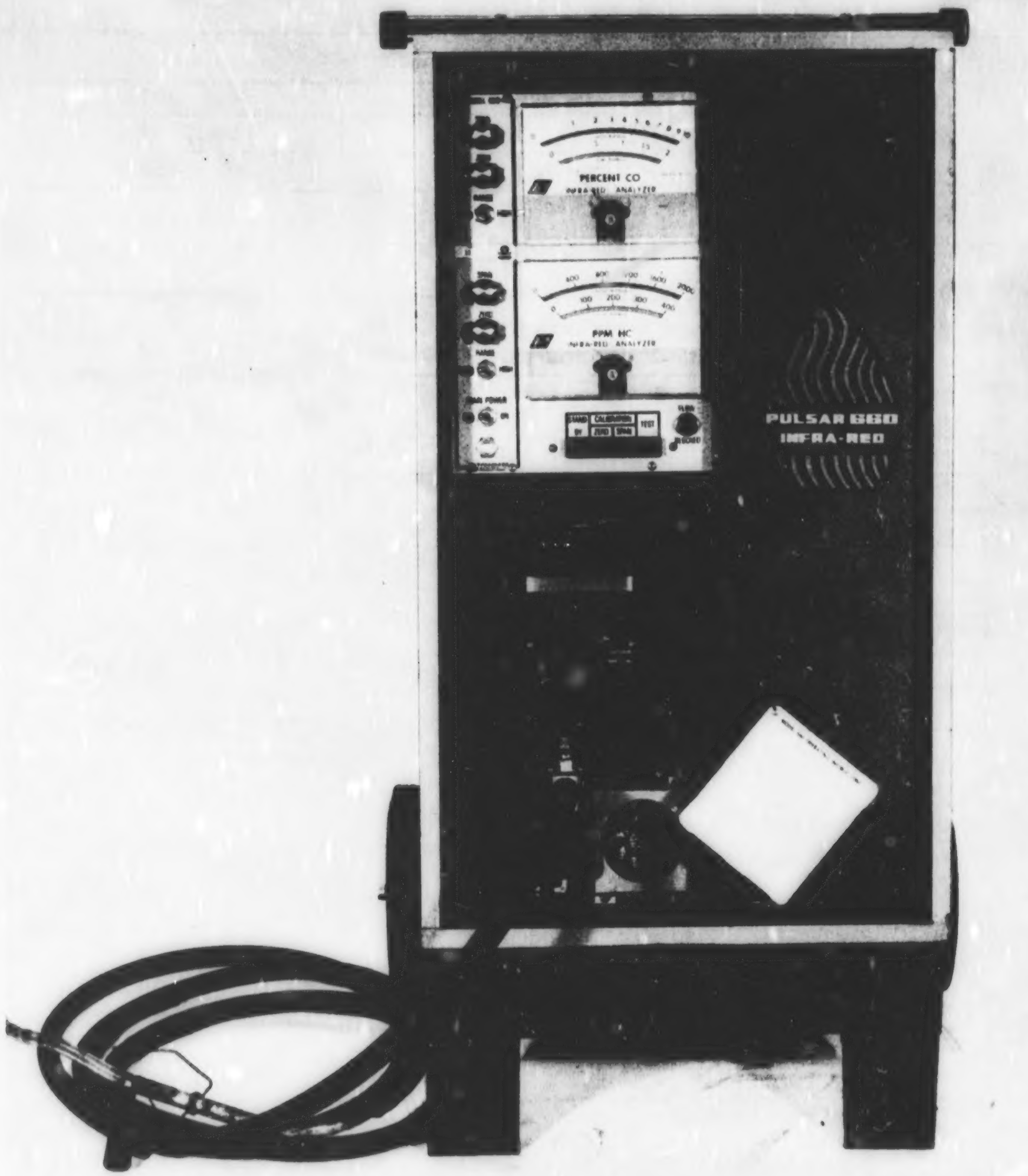
PERCENT CO
INFRA-RED ANALYZER
PPM HC
INFRA-RED ANALYZER
STAND BY
CALIBRATION
ZERO
SPAN
TEST
POWER
ON
PULSAR 660
INFRA-RED

Figure 7-32. PULSAR 662 INFRARED ANALYZER

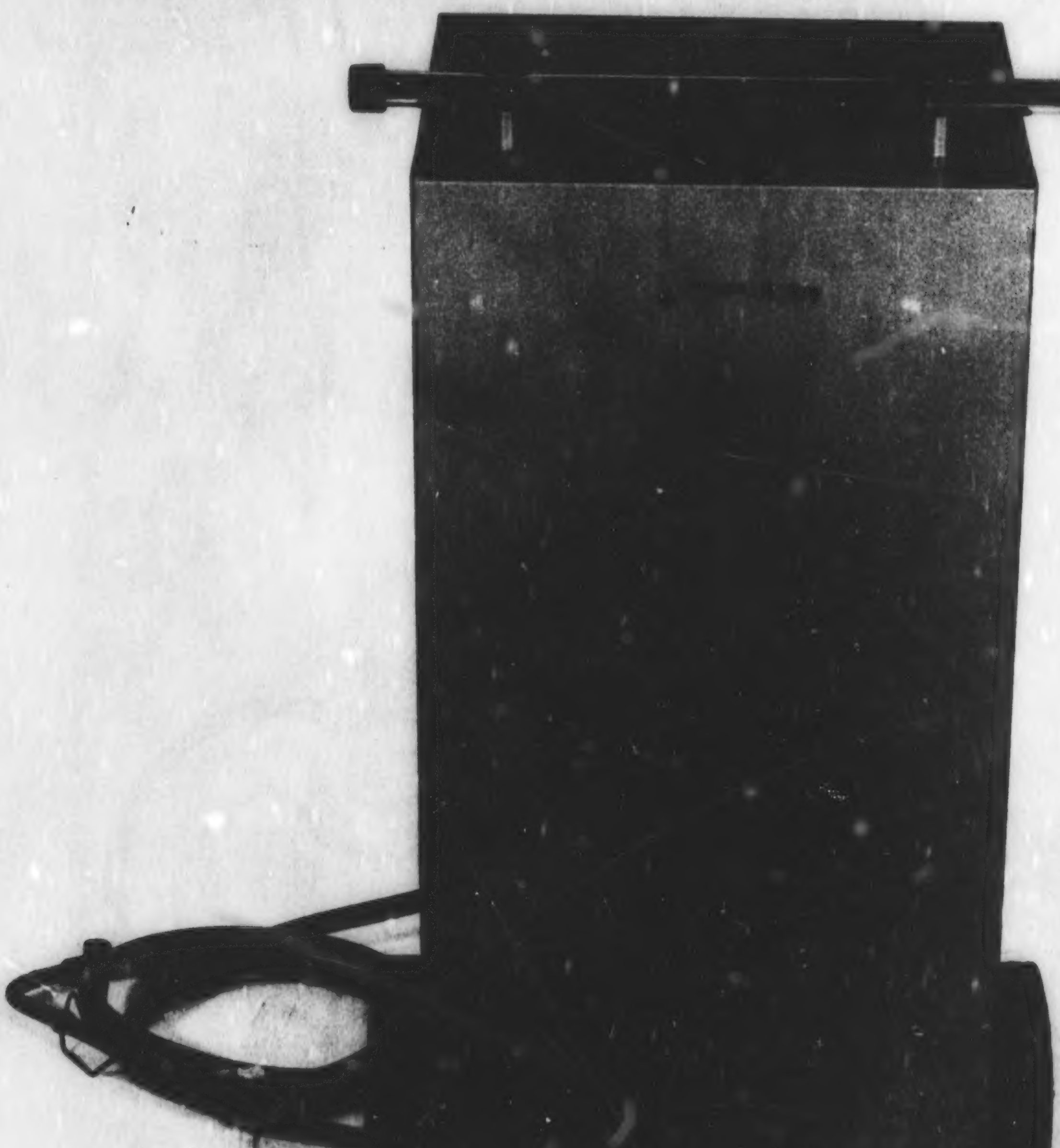

Figure 7-33. PULSAR 662 INFRARED ANALYZER (BACK)

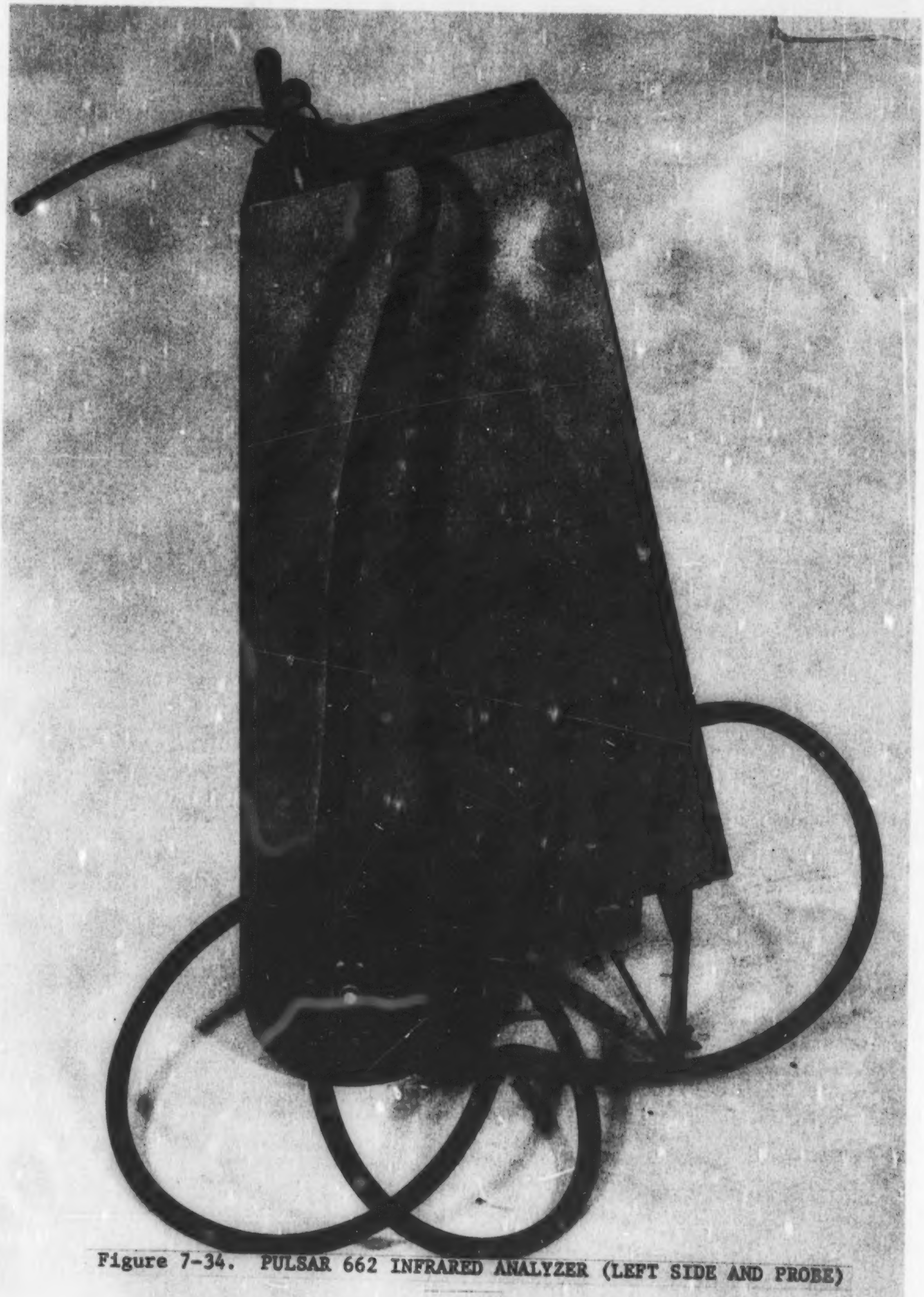

Figure 7-34. PULSAR 662 INFRARED ANALYZER (LEFT SIDE AND PROBE)

7.12 AUTOSCAN 710C HC/CO ANALYZER

Manufacturer - FMC Corporation

Description - HC/CO exhaust analyzer configured as a console model with two wheels. The analyzer cannot be used independent of the cart.

Dimensions -

Height - 48 inches
Width - Base - 19-1/2 inches Analyzer - 10 inches
Depth - 21-1/2 inches
Weight - 81 lbs.

Material of Contruction - Sheet metal cabinet - welded aluminum trim.

Color - Blue with black base and front panel - sliver trim.

Mobility - Two, rear-mounted, 5-inch diameter wheels, front sheet metal support pad. Top, rear-mounted handle. Mobility is good. Feeling during movement is slightly heavy.

Accessories - Sample probe with shot bag, sample hose (25 feet) gas calibration kit, operator's manual.

Control Package -

Front Access - Operation mode switches (four push buttons, all lighted)

1. Standby
2. High (scale)
3. Low (scale)
4. Cal
5. Change filter - indicator light
6. HC zero - knob
7. HC cal - knob
8. CO zero - knob
9. CO cal - knob

Rear Access -
Power on - toggle
2.5 amp breaker
HC course zero - knob
CO course zero - knob

Calibration Mode - (two-position slider switch)

1. Electronic
2. Gas
   Self test switch (nine positions)
   Calibration gas inlet
   Unlabeled HC and CO span adjustments (screws recessed behind blind holes in rear panel - used for factory calibration)

Meters - 8-inch, 90° sweep
Black characters on white background.

Ranges - HC - 0-2000 ppm in 50 ppm increments
- 0-500 ppm in 10 ppm increments
CO - 0-10% in 0.20% increments
- 0-2.0% in 0.02% increments

Air fuel ratio - 14.6 to 11 AFR

Altitude Compensation - Chart on rear panel used during electronic calibration not needed when gas calibrated at test site.

Filters and Sample Handling - Flexible braided tube with rigid tube tip insert, connected to rigid tube with handle. Heavy shot bag chained to probe to hold it in the tail pipe.

Cal Gas Inlet - On rear of unit - automatic cal gas shot with cal button actuation.

Power Requirements - 115 VAC 60 HZ

Operating Principles - Nondispersive infrared, dual cell, optical filter, chopper modulated, dual source, dual solid-state detectors.

Calibration - Normal mode uses automatic calibration gas shot, electronic calibration feature serves as back up system. HC and CO cal knobs used to trim readings to "cal" mark on meters during gas and electronic calibrations. Calibrate mode switch on rear panel selects type of calibration desired.

Operation and Calibration - Very straightforward.

Operation -
1. Plug in and push standby button
2. Set zero
3. Push cal button and set to marks
4. Push high or low button
5. Ready for use

7.12.1 Operational Performance Comments

The mechanical package of this unit consists of a tall, narrow, integral cabinet and stand on a triangular base with wheels at two corners. The unit is slightly top-heavy but the large base, with the calibration gas package located at the bottom, prevents tipping over from being a real problem. There is a hanger attached to the rear of the unit for power cord and sample hose, but there is not additional storage space for instrument manuals or other accessories.

The sample hose is constructed of gray, flexible, reinforced tubing and worked very well during all tests. The unit is designed with a sintered bronze filter located in the aspirated water trap. The water trap configuration presented an uphill flow for any water or particulates in the output line.

An air/fuel ratio scale was included on the CO meter, but the correct CO range for its use was not specified.

Calibration of the instrument with laboratory gases requires removing a threaded cap and fitting a hose adapter to the calibration gas inlet. There are very brief operation and calibration instructions on a plastic card attached to the handle on the back of the unit.

Changing the filter on this unit was awkward because of its location. It was noted during operation that the braided sample probe frayed slightly. The quick disconnect sample hose is a good idea, conducive to easy cleaning and draining.

The instrument incorporates a novel self diagnosis switch that can be used by the customer to help pin point problems prior to calling a service facility. A diagnostic routine is followed while changing switch positions (nine total). The results of these tests are then telephoned to the factory representative who advises on service.

It was noted that meter span set points and interscale correlation are not intended as customer adjustment, although the HC and CO span pots are accessible through unlabeled holes in the rear panel. The manufacturer depends upon initial gas calibration for set point and interscale correlation. Factory service is recommended if span adjustment is needed.

In the laboratory tests, the unit showed warm up times of 9 to 12 minutes except during cold temperature tests, which required 23 minutes.

During the zero drift tests, cycle one and two, the unit experienced an electronic failure causing erratic meter readings. The problem was diagnosed as a faulty data PC board. It was replaced by the service representative and the instrument returned to normal. Cycle three and four indicated a slightly increased low CO error at 35 percent of meter full scale. High altitude operation demonstrated the same general pattern.

Response times for this instrument appeared to range from 16 to slightly more than 19 seconds.

This unit was not responsive to acetylene or benzene. It was most responsive to isobutylene, followed by toluene, methane and ethylene.

The Atuoscan showed no significant repeatable gas interference effects on either scale although the CO scale showed a tendency toward NO sensitivity.

In the vehicle tests, the Autoscan 710C showed the best overall correlation of all instruments.

In the durability test, the Autoscan ran 193 hours before failure (195,700 ppm-hours-HC, 398 percent-hours-CO).

It experienced three test days when the shock test caused greater than a 3 percent meter variation.

The Autoscan average daily span drift was noted to be 1.96 percent full scale HC and 4.5 percent full scale CO.

The filter element was serviced six times during durability tests (3.1 times per 100 hours of operation).

During the durability test, the unit failed when the HC meter was pegged up-scale. The filter light came on and could not be turned off even by removing the hose and filter.

Test data for Autoscan 710C HC/CO Analyzer are shown in Tables 7-56 and through 7-60.

Photographs of this instrument are shown in Figures 7-35, 7-36, and 7-37.

Attachment (1)

Table 7-56. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: AUTOSCAN 710C

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	12	11	23	9
	LOW	CO	MALFUNCTION	9.5	23	10

			MAXIMUM ZERO DRIFT % FULL SCALE			
	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	INSTRUMENT	INSTRUMENT	1.0	1.2
ZERO DRIFT	LOW	CO	MALFUNCTION	MALFUNCTION	0.5	0.5

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	INSTRUMENT					
			MALFUNCTION					

				HC		CO	
ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35		INSTRUMENT	FAILED	
	HIGH	HC/CO	70		NO	DATA	
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				
CYCLE 2	HIGH	HC/CO	35		INSTRUMENT	FAILED	
	HIGH	HC/CO	70		NO	DATA	
	HIGH	HC/CO	100				
	LOW	HC/CO	35				
	LOW	HC/CO	70				
	LOW	HC/CO	100				

Table 7-56. DATA COMPOSITE - LABORATORY TEST (Cont'd)

AUTO SCAN 710C

CYCLE 3	HIGH	HC/CO	35	+ 1.23	+ 0.4	- 8.6	- 3.2
	HIGH	HC/CO	70	- 4.09	- 2.75	- 1.54	- 1.0
	HIGH	HC/CO	100	- 0.94	- 0.8	- 2.17	- 2.0
	LOW	HC/CO	35	- 0.62	- 0.2	+10.14	+ 3.5
	LOW	HC/CO	70	+ 1.45	+ 1.0	0.0	0.0
	LOW	HC/CO	100	+ 2.54	+ 2.4	- 1.71	- 1.5
CYCLE 4	HIGH	HC/CO	35	+ 0.46	+ 0.15	- 1.88	- 0.7
	HIGH	HC/CO	70	- 3.35	- 2.25	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.35	- 0.3	0.0	0.0
	LOW	HC/CO	35	- 6.83	- 2.2	+13.04	+ 4.5
	LOW	HC/CO	70	- 3.77	- 1.6	+ 0.95	+ 0.5
	LOW	HC/CO	100	- 1.69	- 1.6	+ 0.57	+ 0.5
HIGH ALTITUDE	HIGH	HC/CO	35	+ 1.84	+ 0.6	- 0.54	- 0.2
	HIGH	HC/CO	70	- 3.35	- 2.25	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.94	- 0.8	0	0
	LOW	HC/CO	35	0	0	+13.04	+ 4.5
	LOW	HC/CO	70	- 0.86	- 0.4	- 2.86	- 1.5
	LOW	HC/CO	100	+ 1.45	+ 1.0	- 0.57	- 0.5

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1627	INSTRUMENT	"	17.0	19.5
	HIGH	CO	8.1	FAILED NO DATA	"	16.0	19.25

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	10	80	12	35
6750 Feet Altitude	LOW	0	0	5	75	10	30

Table 7-56. DATA COMPOSITE - LABORATORY TEST (Cont'd)

	AUTOSCAN 710C			READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
	POWER	RANGE	SCALE	+ 10%	- 10%
VOLTAGE PROFILE	115V	HIGH	HC	0.35	0.0
	115V	HIGH	CO	0.0	1.0

Table 7-57. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **AUTOSCAN 710C**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	13	24	29	20		
	LOW	CO	13	24	29	20		
ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	1.2	2.0	3.0	2.4		
	LOW	CO	5.0	75.0	6.0	0.5		
GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	1.0	-	0.4	0	0	0
	LOW	CO	0.75	1.0	-	1.0	1.0	0.5
GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	5.0	0	0	1.0
	LOW	CO	0	0	-	0	4.5	0.5
GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0	0	0	0
	LOW	CO	0	0	-	0	0	0
GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0	0	0	0
	LOW	CO	0.5	0	-	0	1.0	0
RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)				
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)	
	HIGH	HC	1627	30	21.5	10.5	9	
	HIGH	CO	8.1	30	20	10	8	

Table 7-57. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

AUTOSCAN 710C

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+0.46	+0.15	-5.91	-2.20
	HIGH	HC/CO	70	-4.83	-3.25	-3.08	-2.00
	HIGH	HC/CO	100	-1.53	-1.30	-3.26	-3.00
	LOW	HC/CO	35	-6.83	-2.20	+15.94	+5.50
	LOW	HC/CO	70	-4.35	-3.00	+4.76	+2.50
	LOW	HC/CO	100	-2.20	+2.86	+2.86	+2.50
CYCLE 2	HIGH	HC/CO	35	+3.53	+1.15	-0.54	-0.20
	HIGH	HC/CO	70	-1.71	-1.25	+0.77	+0.50
	HIGH	HC/CO	100	-0.35	-0.30	-1.09	-1.0
	LOW	HC/CO	35	+8.70	+2.80	+13.04	+4.50
	LOW	HC/CO	70	0	0	+2.86	+1.50
	LOW	HC/CO	100	+0.42	+0.40	+2.86	+2.50
CYCLE 3	HIGH	HC/CO	35	+8.90	+2.90	+3.49	+1.30
	HIGH	HC/CO	70	-0.37	-0.25	+4.62	+3.00
	HIGH	HC/CO	100	+0.83	+0.70	+2.17	+2.00
	LOW	HC/CO	35	+3.11	+1.00	+14.49	+5.0
	LOW	HC/CO	70	+0.58	+0.40	-3.81	-2.00
	LOW	HC/CO	100	+3.32	+3.20	+1.14	+1.00
CYCLE 4	HIGH	HC/CO	35	+3.99	+1.30	-2.96	-1.10
	HIGH	HC/CO	70	-1.86	-1.25	+1.38	+0.90
	HIGH	HC/CO	100	+0.29	+0.25	+1.74	+1.60
	LOW	HC/CO	35	-0.62	-0.20	+14.49	+5.0
	LOW	HC/CO	70	+2.03	+1.40	+0.95	+0.50
	LOW	HC/CO	100	+3.59	+3.40	+1.14	+1.0

Table 7-58. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

AUTOSCAN 710C

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	500/2	HC/CO	50	- 52.03	- 18.44	- 15.07	- 5.5
	500/2	HC/CO	30	- 9.57	- 2.16	- 32.31	- 2.1
	500/2	HC/CO	IDLE	+ 4.06	+ 1.64	- 1.34	- 1.0
CYCLE 2	500/2	HC/CO	50	+ 1.06	+ 0.2	- 3.23	- 1.0
	500/2	HC/CO	30	- 6.66	- 1.54	- 40.0	- 3.0
	500/2	HC/CO	IDLE	+ 3.8	+ 1.72	+ 14.29	+ 7.5
CYCLE 3	500/2	HC/CO	50	- 3.94	- 0.82	- 8.33	- 3.0
	500/2	HC/CO	30	+ 5.67	+ 1.18	- 35.71	- 2.5
	500/2	HC/CO	IDLE	+ 10.82	+ 4.1	- 4.76	- 3.5
CYCLE 4	500/2	HC/CO	50	- 11.85	- 2.5	+ 17.74	+ 5.5
	500/2	HC/CO	30	- 7.54	- 1.68	+ 16.67	+ 1.0
	500/2	HC/CO	IDLE	- 6.59	- 2.82	+ 21.21	+ 14.0
LEAN MODE CYCLE 1	500/2	HC/CO	50	- 6.41	- 1.26	- 10.77	- 3.5
	500/2	HC/CO	30	- 4.81	- 0.96	- 64.29	- 4.5
	2000/2	HC/CO	IDLE	+ 22.02	+ 7.3	- 21.05	- 2.0
CYCLE 2	500/2	HC/CO	50	+ 5.83	+ 1.08	- 1.64	- 0.5
	500/2	HC/CO	30	+ 6.82	+ 1.34	- 1.50	- 0.75
	500/2	HC/CO	IDLE	+ 2.9	+ 2.62	+ 3.7	+ 0.5
CYCLE 3	500/2	HC/CO	50	+ 9.95	+ 1.9	- 10.26	- 4.0
	500/2	HC/CO	30	+ 3.2	+ 0.62	- 41.67	- 2.5
	500/2	HC/CO	IDLE	- 3.79	- 2.52	- 4.76	- 1.0
CYCLE 4	500/2	HC/CO	50	- 3.74	- 0.8	+ 13.85	+ 4.5
	500/2	HC/CO	30	- 1.73	- 0.38	+ 16.67	+ 1.0
	500/2	HC/CO	IDLE	+ 6.02	+ 5.68	+ 17.65	+ 3.0

Table 7-58. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

AUTOSCAN 710C

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC % ERROR ABSOLUTE	HC % ERROR FS	CO % ERROR ABSOLUTE	CO % ERROR FS
RICH MODE CYCLE 1	500/2	HC/CO	50	- 1.96	- 0.38	+ 2.94	+ 1.0
	500/2	HC/CO	30	+ 6.16	+ 1.3	+ 8.33	+ 0.5
	500/10	HC/CO	IDLE	+ 5.62	+ 2.98	+ 10.49	+ 3.4
CYCLE 2	500/2	HC/CO	50	+ 11.90	+ 2.34	- 8.93	- 2.5
	500/2	HC/CO	30	+ 9.0	+ 1.9	- 8.33	- 0.5
	500/10	HC/CO	IDLE	- 1.27	- 0.72	+ 0.27	+ 0.1
CYCLE 3	500/2	HC/CO	50	- 5.21	- 1.1	+ 9.86	+ 3.5
	500/2	HC/CO	30	- 11.35	- 2.56	+ 36.36	+ 2.0
	500/10	HC/CO	IDLE	- 1.11	- 0.64	+ 17.81	+ 6.5
CYCLE 4	500/2	HC/CO	50	- 5.21	- 1.1	- 3.23	- 1.0
	500/2	HC/CO	30	- 4.25	- 1.02	+ 8.33	+ 0.5
	500/10	HC/CO	IDLE	+ 4.20	+ 2.5	+ 13.21	+ 4.9

Table 7-59. DIAGNOSTIC TEST

AUTOSCAN 710 C

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1090	993	+ 9.77	+ 4.85
	10%	CO	2.20	2.11	+ 4.27	+ 0.9
NORMAL IDLE	2000	HC	560	535	+ 4.67	+ 1.25
	10%	CO	2.15	2.04	+ 5.39	+ 1.1
IGNITION ADVANCE	500	HC	475	490	- 3.06	- 3.0
	10%	CO	2.10	2.07	+ 1.45	+ 0.3
IGNITION RETARD	500	HC	475	483	- 1.66	- 1.6
	10%	CO	2.30	2.23	+ 3.14	+ 0.7

Table 7-60. DURABILITY TEST DATA

INSTRUMENT: AUTOSCAN 710C

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	193
HC EXPOSURE (PPM-HRS.)	195,700
CO EXPOSURE (%-HRS.)	398
NO EXPOSURE (PPM-HRS.)	20,070
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	3
SHOCK TEST FAILURE RATE (Failure/Day %)	25.0
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	1
HC SPAN	1
CO ZERO	0
CO SPAN	1
AVERAGE DAILY SPAN DRIFT	
HC%	1.96
CO%	4.5
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER TOTAL PER 100 HRS.	 6 3.11
B DRAIN HOSE TOTAL PER 100 HRS.	 -- --
C REZERO TOTAL PER 100 HRS.	-- --
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	 -- --
E. OTHER TOTAL PER 100 HRS.	 -- --

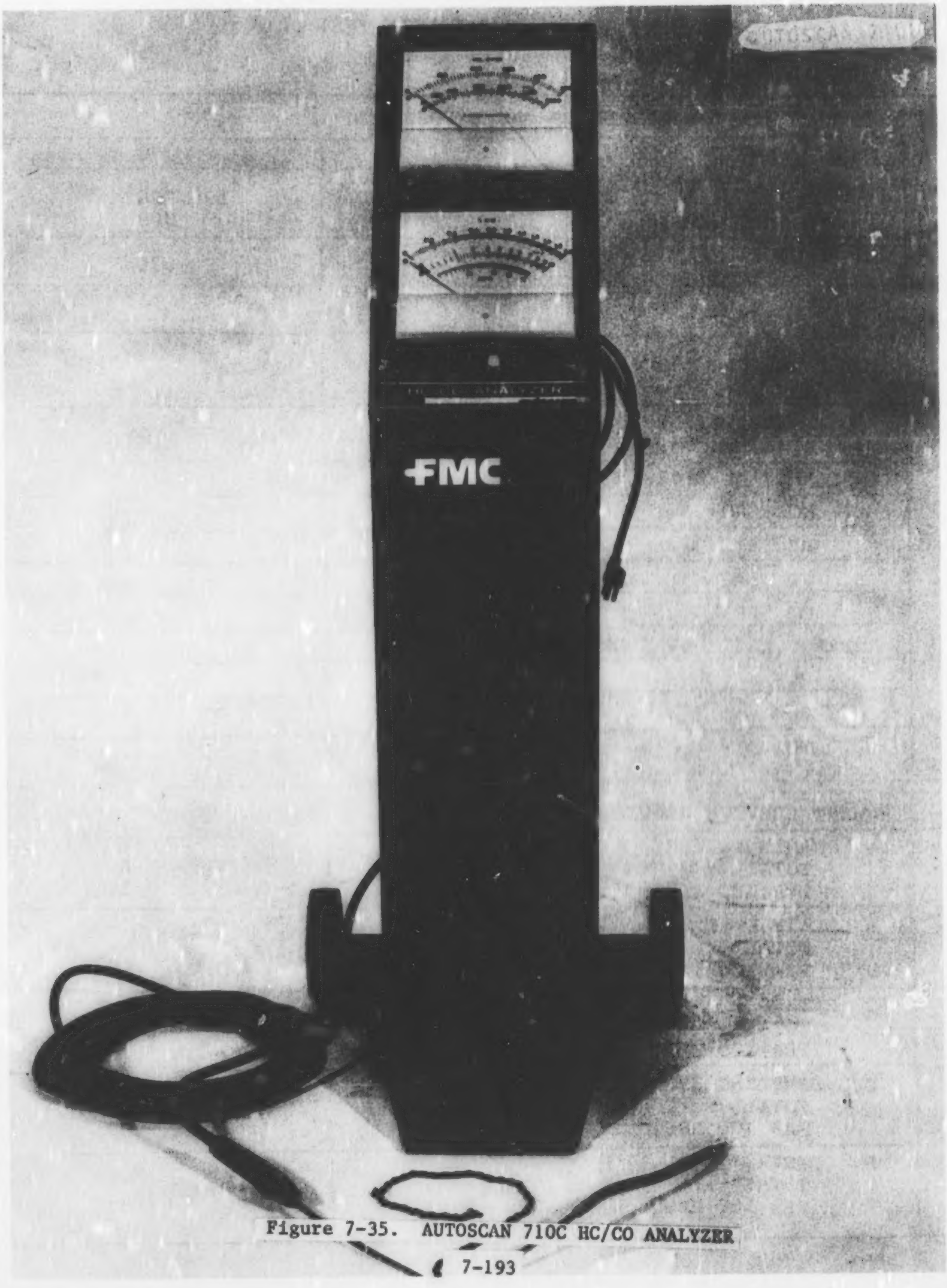
FMC
HC/CO ANALYZER

Figure 7-35. AUTOSCAN 710C HC/CO ANALYZER

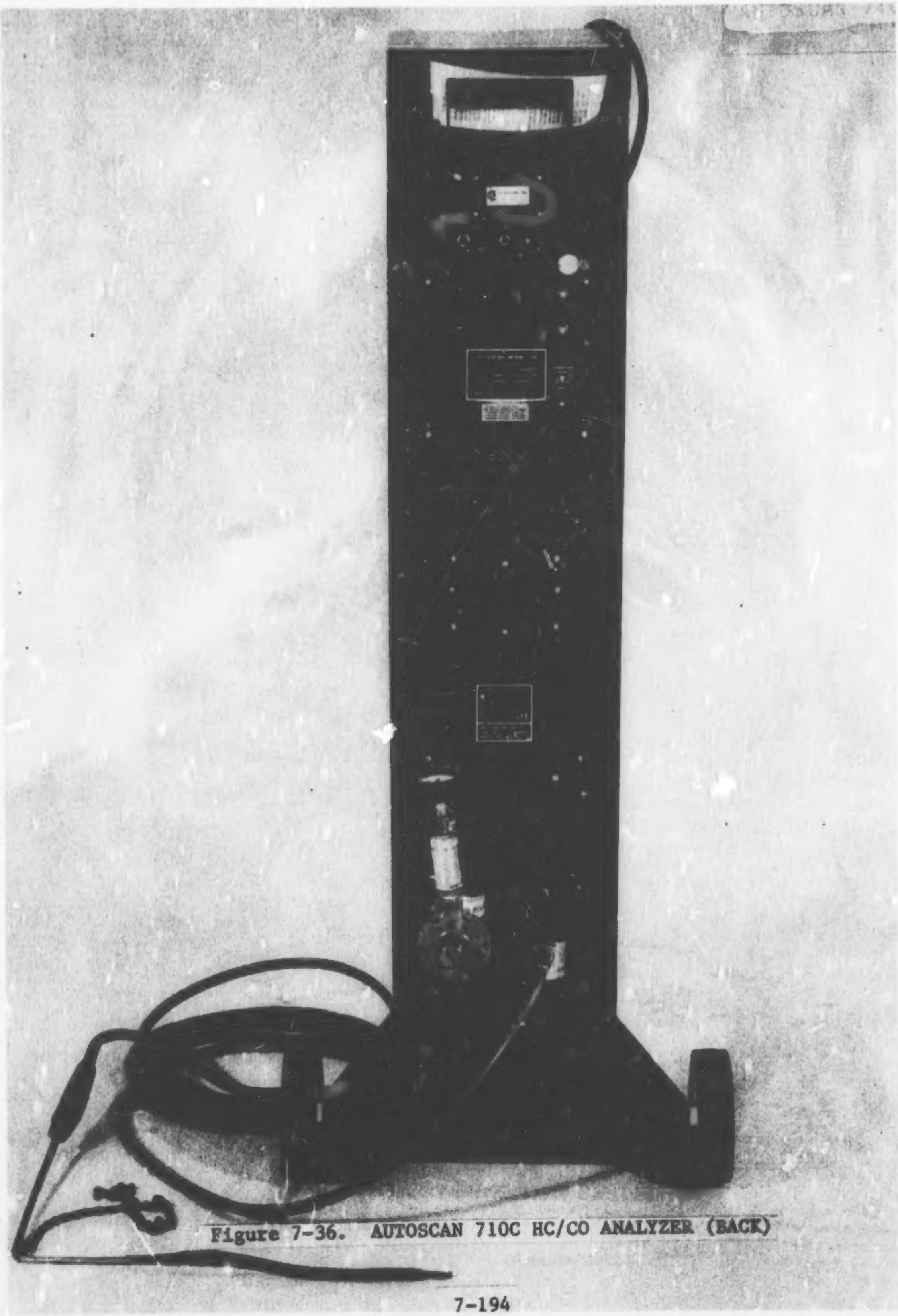

Figure 7-36. AUTOSCAN 710C HC/CO ANALYZER (BACK)

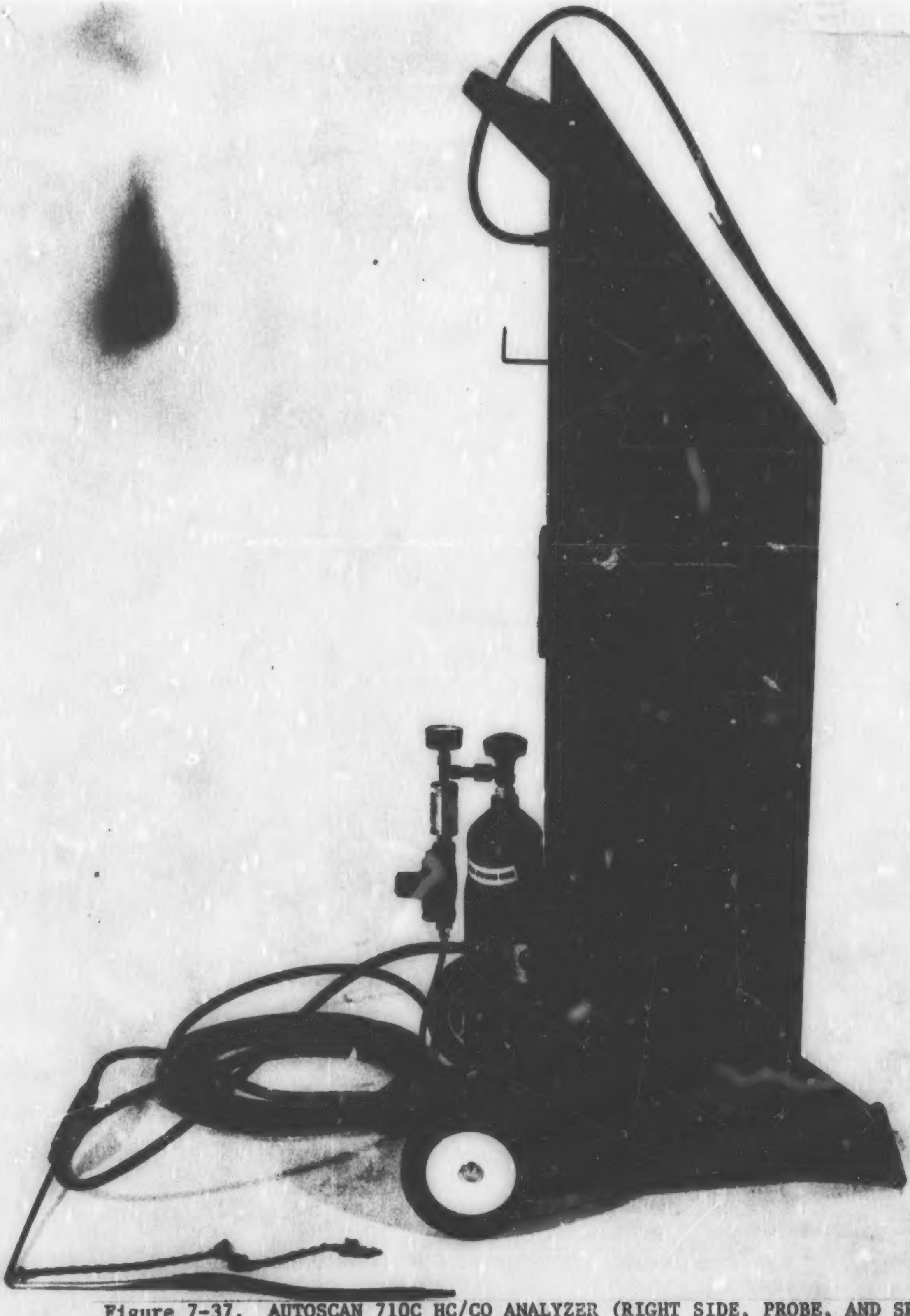

Figure 7-37. AUTOSCAN 710C HC/CO ANALYZER (RIGHT SIDE, PROBE, AND SPAN GAS CONTAINER)

7.13 ALLEN 23-160 CA CO/HC INFRARED EXHAUST EMISSION ANALYZER

Manufacturer - Allen Testproducts Division, The Allen Group Inc.

Description - HC/CO exhaust analyzer configured as a console instrument. The instrument cart is equipped with two wheels.

Dimensions -

Height - 41 inches
Width - 19-1/2 inches
Depth - 17-1/2 inches

Material of Construction - Sheet steel, welded and screwed together. Handle is extruded aliminum tubing.

Color - White with wood-grain front panel.

Mobility - Two, rear-mounted, 6-inch diameter wheels. Front-mounted steel legs. Top rear handle location. Mobility is good with good C.G. location.

Accessories - Sample probe, 25-foot sample hose, tail pipe clamp and operator's manual.

Control Package -

Front Access - Off/On - Range switch (three positions)
1. Off
2. High
3. Low

Mode Control Switch - (three-position)
1. Cal
2. Norm
3. Span
4. Flow indicator (light
5. Pump on/off (Rocker switch)
6. CO zero - double know (course external, fine internal)
7. CO Cal 1 - Sunken screw
8. CO Cal 2 - Sunken screw
9. CO Span - Sunken screw
10. HC zero - double knob (course external, fine internal)
11. HC span - Sunken screw
12. HC Cal 1 - Sunken screw
13. HC Cal 2 - Sunken screw
14. Range indicator lights - two per meter

Rear Access -
3 amp breaker
Cal gas inlet

Meters - 8-inch, 90° sweep - unlighted
Black characters on white face with red band across graduations.

Ranges - HC - 0-2000 ppm in 20 ppm increments
- 0-500 ppm in 10 ppm increments
CO - 0-10% in 0.2% increments
- 0-2.5% in 0.1% increments

Span (altitude correction) scales on both HC and CO meters.

Meters were not sensitive to static electricity.

Altitude Compensation - Chart in operator's manual used in conjunction with "span" graduations on meters. Adjustment using Cal 1 pots not needed when gas calibrated at test site.

Probe - Short section of flexible spiral tubing attached to longer rigid tube fitted with handle. Fine mesh screen located at probe tip.

Filters and Sample Handling - Two series-connected water traps with internal-sintered bronze filters. Air-cooled moisture condenser is internal. Secondary water trap is self-draining.

Cal Gas Inlet - Rear panel

Power Requirements - 115 VAC 60 HZ.

Operating Principles - Dual cell, nondispersive infrared using hot wire sources, solid-state detectors, optical filters and chopper wheel.

Calibration - Operation and calibration instructions printed on rear panel. Internal electronic calibration and gas calibration as back up. Span adjustment requires screwdriver.

Operation and Calibration - Fairly straightforward. Unit is warmed up with pump on.

Operation -
1. Plug in
2. Select High or Low range
3. Turn pump on
4. Warm up
5. Set in Norm or Cal position
6. Set zero or high or low scale
7. Turn to span position
8. Set span (altitude)
9. Turn to Norm, ready for use
10. Optional gas calibration

7.13.1 Operational Performance Comments

The mechanical package for this unit has the meter housing located on the top of the unit, tilted back slightly for better visibility. The meter housings are attached to the rear handle loop of the two-wheeled cabinet. The cabinet is fully enclosed with no doors or storage space except for a desk-like platform below the meters. The unit is equipped with hangers for both the sample hose and the power line.

The sample system consists of a probe that has a short section of flexible spiral tubing on the end. This probe presented no problems during use except that the screen located at the tip of the probe came loose. This unit utilized a well designed flexible reinforced sample hose, gray in color. The sample hose was connected to the water trap, and did not incorporate a quick disconnect. The two water traps on this unit use bronze filters. The first water trap is manually drained. The second water trap is aspirated by the sample pump. The unit had its sample inlet mislabeled as "outlet."

During normal operation of the Allen analyzer, the FLOW indicating light was on. This light was red, and it would be less confusing if it were green, since when lighted it indicates a normal condition. A burned out lamp is easier to detect with this system, but lamp failure will likely occur more often. The fact that the light goes out during flow restriction is somewhat confusing.

The Allen analyzer uses two sample tubes and two reference tubes in its infrared section. This utilizes two 8-inch meters equipped with range indicating lights. The meters had altitude correction numbers imprinted on their face. In using this instrument it was noted that the needless on the meters oscillated. Readings would also change slightly from time to time without explanation. There were very good operating, calibration and service instructions printed on the unit. However, they are located on the rear panel behind the hose hanger making them somewhat difficult to see.

This unit had a generally good control layout except for the span and calibration adjustments vehicles were slotted pots located inside of holes on the front panel and somewhat difficult to adjust. The calibration gas inlet was inconveniently located at the bottom of the rear panel.

In the laboratory tests, the Allen showed warm up time variation form 8 to 12.5 minutes under normal temperatures. During high temperature tests, the warm up time increased to 15 minutes, and under cold temperatures the warm up significantly increased to 40 minutes. Zero drift performance for CO scale was very good for all temperature conditions hitting a maximum of 2 percent full scale at 110°F. This indicated definite temperature sensitivity.

This unit showed essentially no response to any of the interference gases.

The Allen was rated seventh most accurate in the accuracy determination tests. Low scale CO appeared to be the most obvious problem area. Additionally, operations at 110°F indicated generally poor accuracy performance. Again, high altitude tests indicated low scale CO gas correlation problems.

The response times for this instrument varied between 8 and 16 seconds.

This unit was essentially, not responsive to acetylene, benzene, ethylene and methane. It was most sensitive to isobutylene, followed by toluene.

Voltage flunctuation caused essentially no meter response. In the repeatability tests, the warm up times showed long warm up during cycle two. The large change in time cannot be completely explained.

In the vehicle tests, the Allen was fifth best overall in correlation with the EPA bench. The most prevalent problem appeared to be low scale HC readings at idle.

In the durability test, the Allen completed 384 hours of operation. This corresponds to 338,688 ppm-hours of HC exposure and 242 percent-hours of CO exposure. During durability tests, the Allen experienced 8 days when the shock tests caused more than 3 percent meter variation. The instrument demonstrated an average daily span drift of 4.48 percent full scale for HC and 5.23 percent full scale for CO. This unit required 15 filter changes during durability tests (3.9 changes per 100 hours).

With regard to maintenance, it was noted that in normal operation the primary water trap became approximately half full of water. The second water trap aspirated any additional water from the sample line. The bronze filters on this unit are of moderate pore size. They needed less frequent service than other bronze filters of a finer pore size. During the durability test phase, servicing of the water traps and filters resulted in breakage of the plastic filter mount. It was subsequently replaced.

The Allen analyzer failed and durability test when the CO meter began intermittently dropping to zero. Eventually the CO Meter no longer responded to calibration gas.

Test data for Allen 23-160CA CO/HC Infrared Exhaust Emission Analyzer are shown in Tables 7-61 through 7-65.

Photographs of this instrument are shown in Figures 7-38 through 7-41.

Table 7-61. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: ALLEN 23 160 CA

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
	LOW	HC	9	15	40	12.5		
	LOW	CO	8	15	40	10		
	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE					
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)		
ZERO DRIFT	LOW	HC	0	18.0	4.0	2.0		
	LOW	CO	0	2.0	0	0		
GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	HC	0	-	0	0	0.6	0
	LOW	CO	0	0	-	0	0	0
ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO		
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS	
CYCLE 1	HIGH	HC/CO	35	+ 6.1	+ 2.1	0.0	0.0	
	HIGH	HC/CO	70	- 0.28	- 0.2	+ 3.85	+ 2.5	
	HIGH	HC/CO	100	- 0.61	- 0.55	0.0	0.0	
	LOW	HC/CO	35	- 1.13	- 0.4	+10.14	+ 2.8	
	LOW	HC/CO	70	+ 0.27	+ 0.2	- 2.86	- 2.0	
	LOW	HC/CO	100	+ 0.49	+ 0.4	- 4.55	- 4.0	
CYCLE 2	HIGH	HC/CO	35	+ 6.83	+ 2.35	- 7.26	- 2.7	
	HIGH	HC/CO	70	+19.89	+14.1	- 4.62	- 3.0	
	HIGH	HC/CO	100	- 1.06	- 0.95	- 0.54	- 0.5	
	LOW	HC/CO	35	+ 2.82	+ 1.0	-12.38	- 5.2	
	LOW	HC/CO	70	+ 3.02	+ 2.2	- 7.43	- 5.2	
	LOW	HC/CO	100	> +22.0	> +16.0	- 7.27	- 6.4	

ALLEN 23-160 CA Table 7-61. DATA COMPOSITE - LABORATORY TEST (Cont'd)

CYCLE 3	HIGH	HC/CO	35	+ 1.74	+ 0.6	-12.63	- 4.7
	HIGH	HC/CO	70	- 1.27	- 0.9	+ 1.54	+ 1.0
	HIGH	HC/CO	100	- 2.74	- 2.45	0.0	0.0
	LOW	HC/CO	35	- 1.13	- 0.4	- 2.86	- 1.2
	LOW	HC/CO	70	- 0.55	- 0.4	- 5.71	- 4.0
	LOW	HC/CO	100	- 0.4	- 0.4	- 4.55	- 4.0
CYCLE 4	HIGH	HC/CO	35	+ 4.65	+ 1.6	+ 2.15	+ 0.8
	HIGH	HC/CO	70	- 1.27	- 0.9	0.0	0.0
	HIGH	HC/CO	100	- 1.34	- 1.2	0.0	0.0
	LOW	HC/CO	35	- 1.13	- 0.4	- 4.76	- 2.0
	LOW	HC/CO	70	+ 1.65	+ 1.2	- 8.57	- 6.0
	LOW	HC/CO	100	+ 0.73	+ 0.6	- 4.55	- 4.0
HIGH ALTITUDE	HIGH	HC/CO	35	+ 7.56	+ 2.6	+ 1.61	+ 0.6
	HIGH	HC/CO	70	- 1.27	- 0.9	- 1.54	+ 1.0
	HIGH	HC/CO	100	- 0.22	- 0.2	+ 2.17	+ 2.0
	LOW	HC/CO	35	+ 2.82	+ 1.0	- 4.76	- 2.0
	LOW	HC/CO	70	+ 1.65	+ 1.2	- 5.71	- 4.0
	LOW	HC/CO	100	+ 4.21	+ 4.2	- 6.82	- 6.0

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1716	10.8	8.25	11.4	16.25
	HIGH	CO	8.1	10.9	7.55	11.25	16.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	LOW	0	0	0	75	5	25
6750 Feet Altitude	LOW	0	0	5	80	10	25

Table 7-61. DATA COMPOSITE - LABORATORY TEST (Cont'd)

ALLEN 23-160 CA

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	HC	0	0.55
	115V	HIGH	CO	0	0

Table 7-62. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: ALLEN 23-160 CA

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	8	28	9	19
		CO	6	26	9	10

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	HC	1.2	2.0	3.0	2.4
		CO	5.0	75.0	6.0	0.5

GAS INTERFERENCE (% of FS)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
CYCLE 1	LOW	HC	0	--	0	0	2.0	0
		CO	0.08	1.2	--	0	0	0
CYCLE 2	LOW	HC	0	---	1.0	0	1.0	0
		CO	0.4	0.8	---	0	3.6	0
CYCLE 3	LOW	HC	1.6	---	0.6	2.0	0	0
		CO	0	0	---	0	0	0
CYCLE 4	LOW	HC	1.0	---	---	0	0	0
		CO	0	0	---	0.8	0.8	1.2

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE &	HIGH	HC	1716	22.5	20	6.5	7
		CO	8.1	22.5	17.5	6.5	7.5

Table 7-62. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ALLEN 23-160 CA

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	- 1.16	- 0.40	+ 4.84	+ 1.80
	HIGH	HC/CO	70	- 6.91	- 4.90	+ 5.39	+ 3.50
	HIGH	HC/CO	100	- 6.09	- 5.45	+ 5.44	+ 5.00
	LOW	HC/CO	35	-12.43	- 4.40	+ 1.91	+ 0.80
	LOW	HC/CO	70	- 9.34	- 6.80	+ 0.57	+ 0.40
	LOW	HC/CO	100	- 4.81	- 4.80	+ 0.46	+ 0.40
CYCLE 2	HIGH	HC/CO	35	+ 7.56	+ 2.60	+10.22	+ 3.80
	HIGH	HC/CO	70	- 1.27	- 0.90	+ 4.62	+ 3.0
	HIGH	HC/CO	100	+ 1.17	+ 1.05	+ 8.70	+ 8.0
	LOW	HC/CO	35	- 3.95	- 1.40	- 2.86	- 1.20
	LOW	HC/CO	70	- 2.47	- 1.80	- 5.14	- 3.60
	LOW	HC/CO	100	- 0.80	- 0.80	- 2.27	- 0.01
CYCLE 3	HIGH	HC/CO	35	+11.92	+ 4.10	+ 0.24	+ 0.80
	HIGH	HC/CO	70	+ 2.26	+ 1.60	+ 5.39	+ 3.50
	HIGH	HC/CO	100	+ 1.73	+ 1.55	+ 3.80	+ 3.50
	LOW	HC/CO	35	- 5.09	- 1.80	- 3.81	- 1.60
	LOW	HC/CO	70	- 0.55	- 0.40	+ 0.57	+ 0.40
	LOW	HC/CO	100	- 2.00	- 2.00	- 3.18	- 2.80
CYCLE 4	HIGH	HC/CO	35	+10.47	+ 3.60	+ 1.61	+ 0.60
	HIGH	HC/CO	70	+ 0.14	+ 0.10	- 1.54	- 1.0
	HIGH	HC/CO	100	+ 0.62	+ 0.55	- 0.22	- 0.20
	LOW	HC/CO	35	- 1.70	- 0.60	+ 3.81	+ 1.60
	LOW	HC/CO	70	- 0.82	- 1.00	+ 0.57	+ 0.40
	LOW	HC/CO	100	- 1.00	- 1.00	- 0.93	- 0.80

Table 7-63. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

ALLEN 23-160 CA

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	500/2.5	HC/CO	50	- 11.07	- 2.24	- 1.32	- 0.4
	500/2.5	HC/CO	30	- 2.48	- 0.56	- 14.29	- 0.8
	500/2.5	HC/CO	IDLE	- 8.55	- 3.74	+ 19.15	+ 10.8
CYCLE 2	500/2.5	HC/CO	50	- 14.89	- 2.8	+ 20.0	+ 4.8
	500/2.5	HC/CO	30	- 9.57	- 2.16	- 33.33	- 2.0
	500/2.5	HC/CO	IDLE	+ 15.29	+ 7.16	+ 27.36	+ 11.6
CYCLE 3	500/2.5	HC/CO	50	- 8.44	- 1.66	0	0
	500/2.5	HC/CO	30	+ 7.21	+ 1.48	- 21.43	- 1.2
	500/2.5	HC/CO	IDLE	+ 35.21	+ 13.02	+ 37.68	+ 20.8
CYCLE 4	500/2.5	HC/CO	50	- 3.32	- 0.7	+ 20.97	+ 5.2
	500/2.5	HC/CO	30	- 5.75	- 1.28	0	0
	500/2.5	HC/CO	IDLE	+ 2.54	+ 1.04	+ 18.32	+ 9.6
LEAN MODE CYCLE 1	500/2.5	HC/CO	50	+ 6.82	+ 1.34	+ 12.90	+ 3.2
	500/2.5	HC/CO	30	+ 12.80	+ 2.52	- 7.69	- 0.4
	2000/2.5	HC/CO	IDLE	+ 12.56	+ 4.13	+ 15.00	+ 1.2
CYCLE 2	500/2.5	HC/CO	50	+ 7.99	+ 1.48	+ 31.58	+ 7.2
	500/2.5	HC/CO	30	+ 9.95	+ 1.9	+ 20.0	+ 0.4
	500/2.5	HC/CO	IDLE	+ 12.76	+ 11.28	+ 20.69	+ 2.4
CYCLE 3	500/2.5	HC/CO	50	+ 37.17	+ 7.1	+ 16.44	+ 4.8
	500/2.5	HC/CO	30	+ 32.35	+ 6.34	+ 9.09	+ 0.4
	500/2.5	HC/CO	IDLE	+ 7.42	+ 5.24	+ 37.5	+ 6.0
CYCLE 4	500/2.5	HC/CO	50	+ 3.32	+ 0.72	+ 4.48	+ 1.2
	500/2.5	HC/CO	30	+ 0.09	+ 0.02	- 14.29	- 0.8
	500/2.5	HC/CO	IDLE	+ 4.64	+ 3.94	+ 25.0	+ 3.2

Table 7-63. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

ALLEN 23-160 CA

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	500/2.5	HC/CO	50	- 1.96	- 0.38	+ 15.38	+ 4.0
	500/2.5	HC/CO	30	- 1.87	- 0.4	- 8.33	- 0.4
	500/10	HC/CO	IDLE	+ 25.1	+ 12.84	+ 11.82	+ 3.7
CYCLE 2	500/2.5	HC/CO	50	+ 1.73	+ 0.34	+ 15.25	+ 3.6
	500/2.5	HC/CO	30	+ 9.19	+ 2.02	+ 8.33	+ 0.4
	500/10	HC/CO	IDLE	+ 21.21	+ 11.9	+ 9.59	+ 3.5
CYCLE 3	500/2.5	HC/CO	50	+ 3.14	+ 0.68	+ 4.17	+ 1.2
	500/2.5	HC/CO	30	+ 1.95	+ 0.44	0	0
	500/10	HC/CO	IDLE	+ 24.57	+ 16.04	+ 16.09	+ 6.1
CYCLE 4	500/2.5	HC/CO	50	- 12.8	- 2.7	+ 19.40	+ 5.2
	500/2.5	HC/CO	30	- 16.74	- 4.02	0	0
	500/10	HC/CO	IDLE	+ 9.78	+ 6.06	+ 13.40	+ 5.2

Table 7-64. DIAGNOSTIC TEST

ALLEN 23-160 CA

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1300	1217	+ 6.82	+ 4.15
	10%	CO	2.40	2.21	+ 8.6	+ 1.9
NORMAL IDLE	2000	HC	700	677	+ 3.4	+ 1.15
	10%	CO	2.60	2.47	+ 5.26	+ 1.3
IGNITION ADVANCE	2000	HC	580	502	+ 15.54	+ 3.9
	10%	CO	2.50	2.33	+ 7.3	+ 1.7
IGNITION RETARD	2000	HC	540	488	+ 10.66	+ 2.6
	10%	CO	2.50	2.32	+ 7.76	+ 1.8

Table 7-65. DURABILITY TEST DATA

INSTRUMENT: ALLEN 23-160 CA

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	384
HC EXPOSURE (PPM-HRS.)	338,688
CO EXPOSURE (%-HRS.)	242
NO EXPOSURE (PPM-HRS.)	39,168
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	9
SHOCK TEST FAILURE RATE (Failure/Day %)	39.13
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	2
HC SPAN	2
CO ZERO	0
CO SPAN	7
AVERAGE DAILY SPAN DRIFT	
HC%	4.48
CO%	5.23
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	15
PER 100 HRS.	3.91
B DRAIN HOSE	
TOTAL	9
PER 100 HRS.	2.34
C REZERO	
TOTAL	1
PER 100 HRS.	0.26
D. SAMPLING SYSTEM	
TOTAL	1
PER 100 HRS.	0.26
E. OTHER	
TOTAL	--
PER 100 HRS.	--

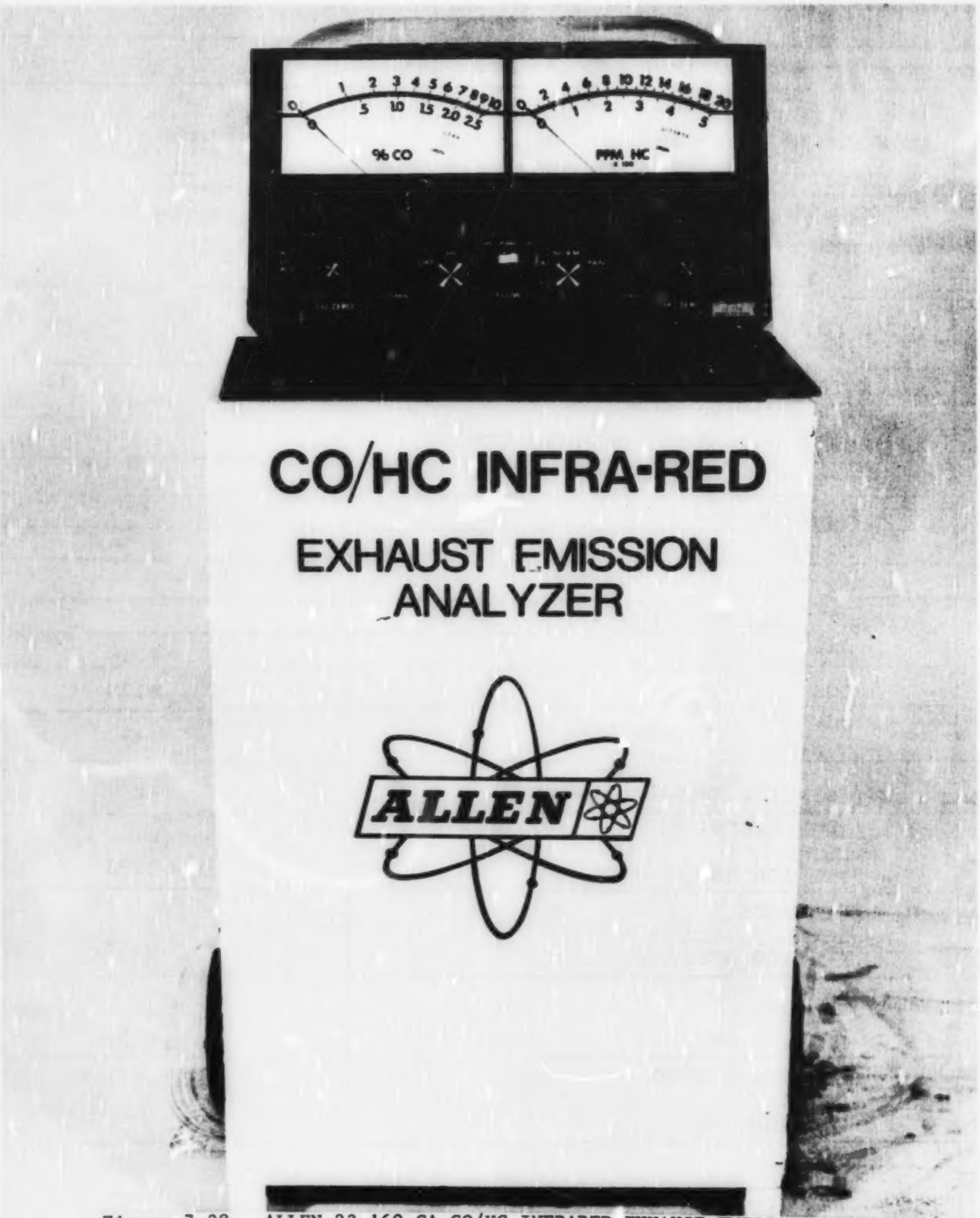
% CO
PPM HC
CO/HC INFRA-RED
EXHAUST EMISSION
ANALYZER
ALLEN

Figure 7-38. ALLEN 23-160 CA CO/HC INFRARED EXHAUST EMISSION ANALYZER

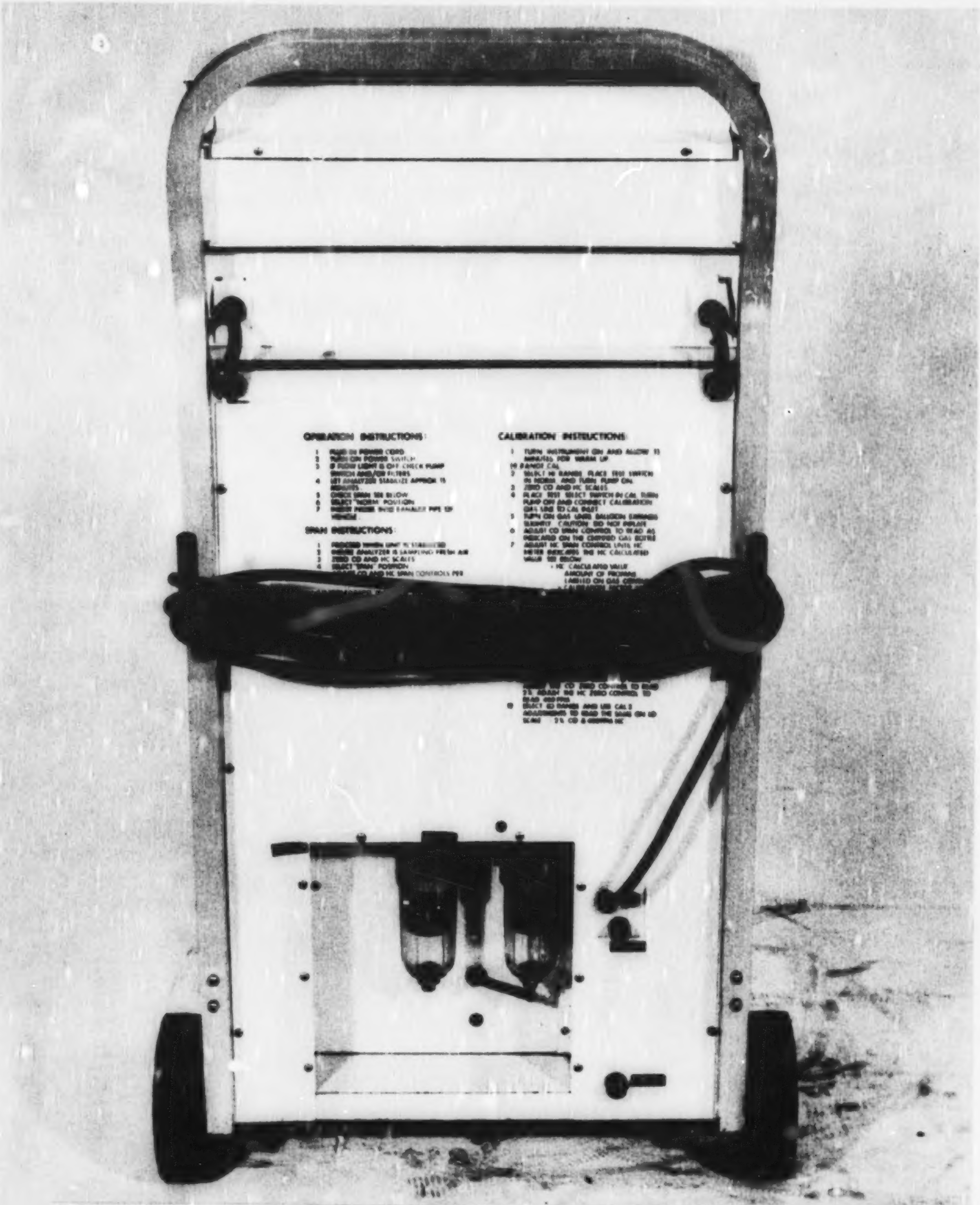
OPERATION INSTRUCTIONS:
SPAN INSTRUCTIONS:
CALIBRATION INSTRUCTIONS:

Figure 7-39. ALLEN 23-160 CA CO/HC INFRARED EXHAUST EMISSION ANALYZER (BACK)

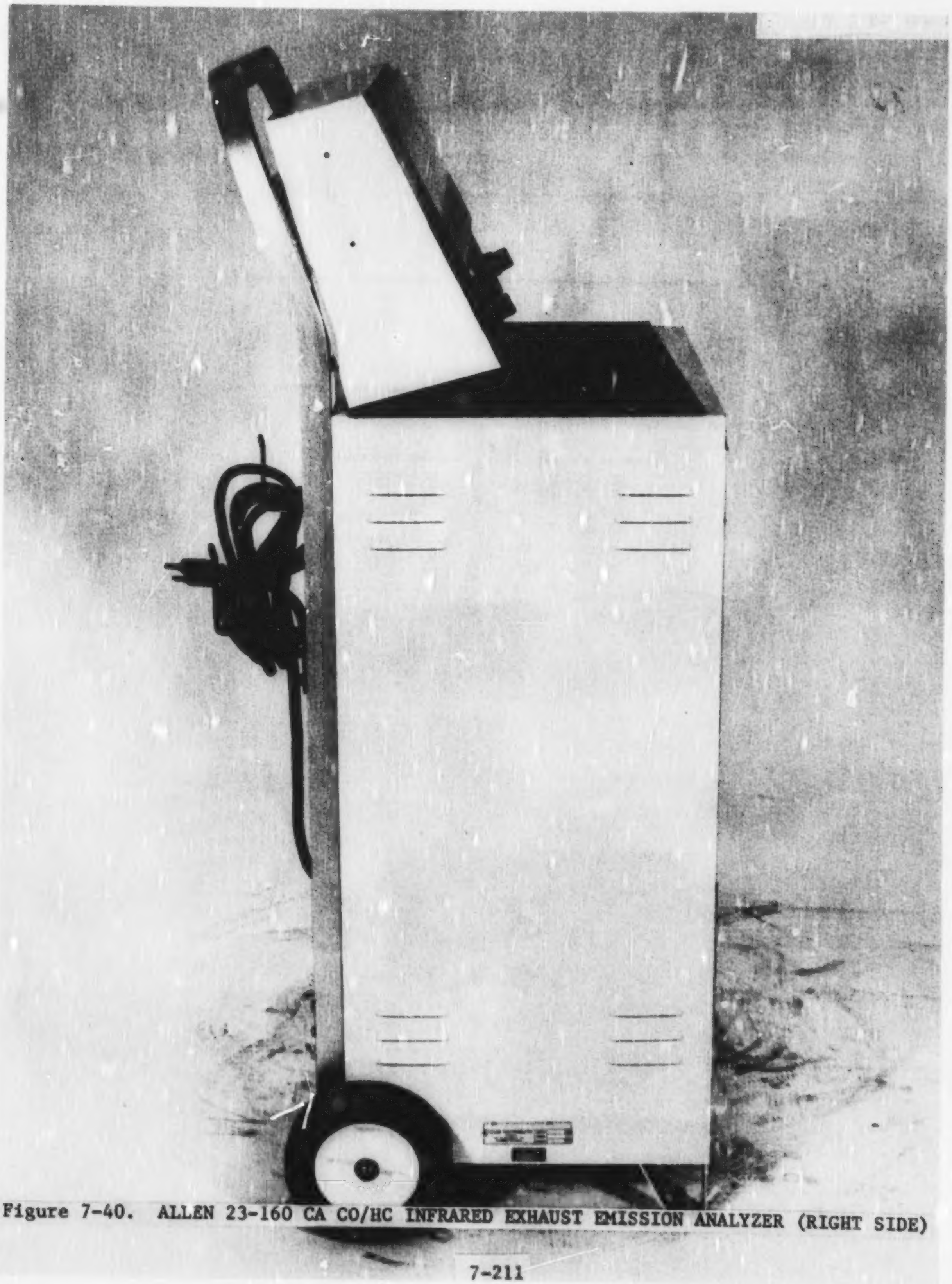

Figure 7-40. ALLEN 23-160 CA CO/HC INFRARED EXHAUST EMISSION ANALYZER (RIGHT SIDE)

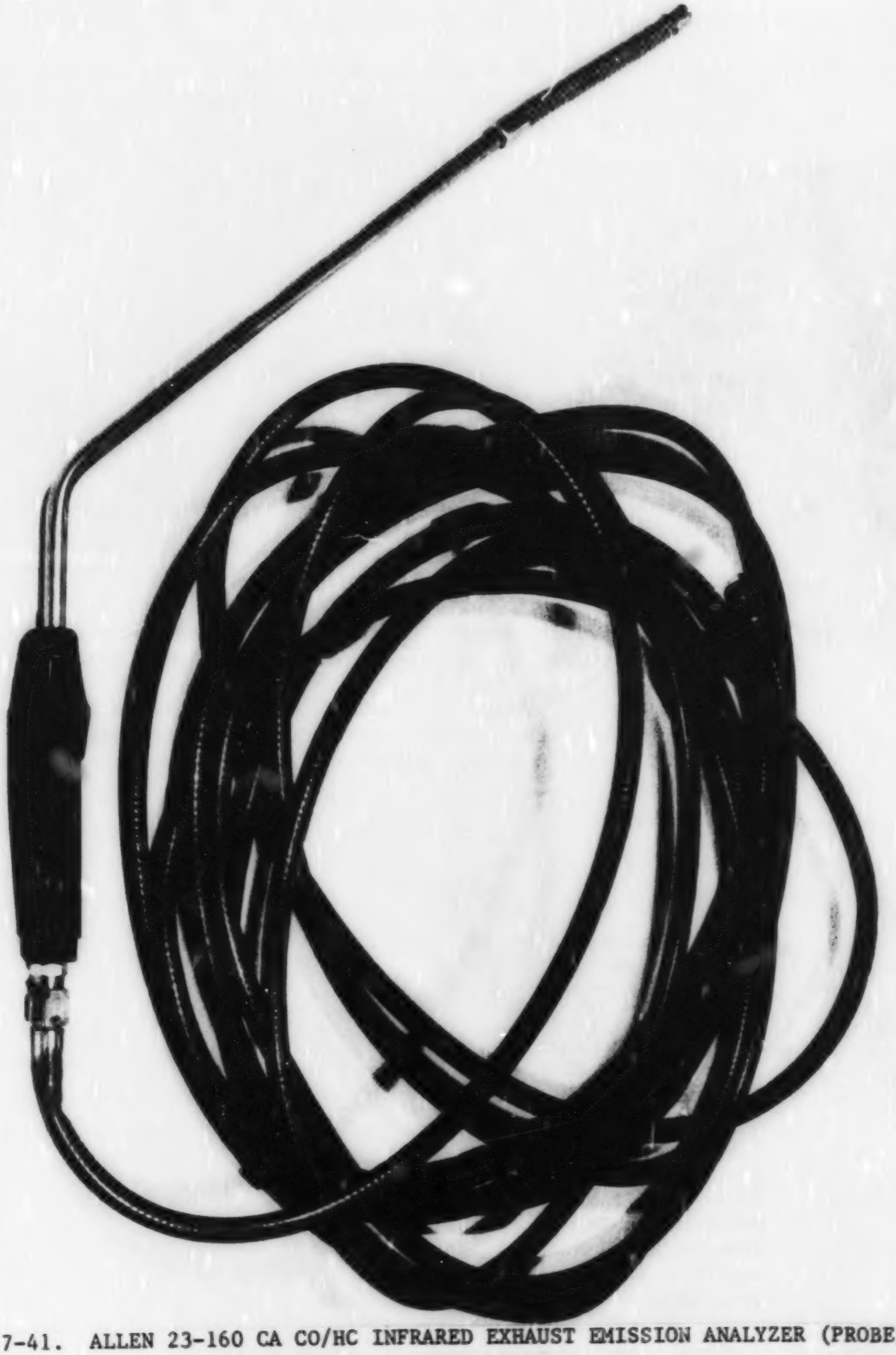

Figure 7-41. ALLEN 23-160 CA CO/HC INFRARED EXHAUST EMISSION ANALYZER (PROBE)

7.14 AUTOSENSE 200 ENGINE DIAGNOSTIC AND EXHAUST EMISSION ANALYZER

Manufacturer - Hamilton Test Systems

Description - An integrated package consisting of engine parameter sensors, HC/CO emissions analyzer, computer, tape cassette unit, hand-held controller and printer.

Dimemsions -

Analyzer -
Width - 47 inches
Height - 41 inches
Depth - 26 inches
Weight - 250 lbs

Hand-Held Controller -
8" x 9-5/8 x 1-3/8"
Weight - 3 lbs
Connecting cable length - 30 feet

Material of Construction - Welded sheet steel cabinet, square tube steel handles on each end.

Color - Light blue with white top.

Mobility - Four, 4-inch wheels, two wheels on printer end swivel. Mobility is relatively good considering the weight of this unit.

Accessories - Exhaust probe, sample hose (30 feet) miscellaneous diagnostic sensors, miscellaneous cassettes with diagnostic programs, printer paper. Operator's manual and miscellaneous support documentation.

Control Package -

Front Access -
"Power" button (On/Off)

Side Interior Access -
HC span screw
CO span screw

Hand-held Control -
Enter/verify/print - Push button
1-9 and 0 - Push buttons
(-) - Push button
Start - Push button
 - Push button
Clear - PUsh button
Diagnosis - Push button
Spec On/Off - Push button
Aid No - Test No - Led Display
Test Data - min. limit - Diag. code

Test Condition - max. limit
Enter Aid Number - Small Red Light
Enter Test Number - Small Red Light
Enter Test Data - Small Red Light
Out of Limit - Small Red Light
Sequence Testing - Small Red Light
Diagnostic Code - Small Red Light
Error - Small Red Light
Print Ready - Small Red Light

Meters - Located on hand-held controller .

Three	1-3/4 x 1/2" Led Display
Middle	Display - HC - Digital - Four Digital
Bottom	Display - CO - Digital - Four Digital
Top	Nonemission-related - procedural information identifying operation programs.

Teletype paper printer on left side of analyzer console.

Ranges - HC - 0-2000 ppm
CO - 0-10%

Altitude Compensation - None, must be calibrated at altitude of use.

Probe - "S" curve rigid tube with a convoluted tube end piece. Convoluted tube was fitted with tail pipe clamp; rigid tube was fitted with handle. Sample entrance through side hole in convoluted tube.

Filters and Sample Handling - Fine mesh porous bronze filter located in the automatically aspirated primary water trap. Secondary paper cartridge filter in the secondary, manually drained, water trap.

Cal Gas Inlet - Internal cabinet access left side near front panel. Very careful calibration gas pressure and flow regulation was required.

Power Requirements - 115 VAC 60HZ 6 amps

Operating Principles - Dual cell, nondispersive infrared solid-state detector, hot wire source, band pass optical filters, chopper wheel - digital signal conversion.

Calibration - Automatic zero during each measurement cycle. No manual zero possible. Gas calibration only, no electronic calibration available. Gas calibration is relatively time-consuming and usually requires more than one procedural cycle.

Operation and Calibration - With regard to operation and calibration, the unit required extensive instruction for operator use and a significant amount of experience to interpret the output displays. The unit incorporates an auto-zeroing function that complicates the calibration procedure and makes calibration time-consuming. Calibration of this unit required internal disconnection of the sample input line and connection of the cal gas hose through a precision regulator and an in-line plenum damper. Calibration of this unit required overcompensation of the span adjustments, which were located inside holes in a very awkward location on the interior of the instrument. In general, we found calibration of this instrument to be a very difficult and time-consuming effort.

Calibration Procedure -

1. Power on, warm up for 30 minutes
2. Teletype will print "NO of CYL"
3. Using hand controller enter "8"
4. Teletype will print 8 CYL
5. Teletype will then ask for AID number (Vehicle Identification)
6. Using hand controller enter 934
7. Hand controlled middle and bottom displays will read percent
8. Disconnect sample time and connect span gas, pressure regulator, magnihelic
9. Turn on span gas
10. Adjust meters by use of HC or CO screw pot. (Adjustment should be three times observed deviation; i.e., if gas is 1,600 ppm HC and meter read 1,550, set meter at 1,600 + (3 x 50) + 1,750 ppm.)
11. Push clear
12. Hand control reads 0-0
13. Enter 934
14. Read span gas values on controller
15. If not correct, repeat step 10 through 14 until acceptable reading is achieved.

This overshooting technique saves time but calibration is still very time-consuming.

7.14.1 Operational Performance Comments

The mechanical configuration of this unit was very different from the other units in this program. It has a very large, heavy cabinet that also incorporates a printer and engine diagnostic unit. Operation of this unit was accomplished by using a remote, hand-held display and pushbutton panel. This display served both the engine analyzer and emissions functions. The cabinet was equipped with four wheels, two swiveling and two fixed. Only lateral movement was possible with this configuration.

The engine diagnostic functions required a large number of input cables and hoses, which were a storage problem when not in use.

The sample system on this unit utilized a probe that was a double-curve rigid tube with a convoluted end section. The sample hose was relatively stiff and was difficult to manipulate. This unit incorporated a fine porous bronze filter in the aspirated primary water trap, and a back-up paper cartridge filter in the manually drained secondary water trap.

In the emissions-measuring mode, this unit had slow response and also demonstrated some problems in reading stability.

In the area of maintenance, it was found that filter service was relatively difficult. The bronze porous filter in this unit had excessively fine pores, thus requiring frequent changes. In addition, the specific bronze filter required for this instrument is available only from the manufacturer and acquisition of spare filters required 6 weeks from time of order. The secondary paper filter cartridge collects moisture easily and needed frequent service, especially during the durability test.

During the laboratory test, high temperature cycle (cycle 2), this unit experienced failure in its electrical system. The failure appeared to be confined to the optical bench. The optical bench was returned to the manufacturer and they were advised that during the high temperature test the HC channel became completely inoperative. The channel would not respond at all and the LED display indicated a constant zero reading. The CO channel appeared to function properly but did require recalibration at the high temperature.

Upon return of the optical bench, the service representative advised this laboratory that the PC board was the problem and that the board had been cleaned and was now functioning properly. However, upon examination it was discovered that the optics in the system had been altered and that a new conversion factor sticker had been applied to the unit. The prior conversion factor of 0.596 had been changed to 0.587.

Also, during the laboratory test, the hand-held controller showed erratic display behavior and input to the computer became unpredictable. The controller was checked and a solder bridge was discovered on its circuit board. The bridge was removed and the controller and analyzer returned to proper operation.

In the laboratory tests, the Autosense showed warm up times of 7 to 8 minutes at normal temperatures. At low temperatures, the unit required 15 minutes to achieve stable zero. In the repeatability tests it indicated stabilized operation after only 2 minutes of operation in cycle 3.

With the automatic zero function, the unit showed essentially no zero drift during laboratory tests.

This unit was totally insensitive to the interference gases.

In the accuracy determination tests, this unit was tenth most accurate showing greatest errors at 100 percent scale values. This instrument was single range for both HC anc CO. Accuracy tests were run with span gas values of 100 percent, 70 percent, 35 percent, 20 percent, 10 percent, and 5 percent full scale gas values for both HC and CO scales. High altitude operation showed the same error pattern.

The response time of this instrument indicated a wide variation in CO and HC response times. Times varied between 12.5 seconds for CO to 55 seconds for HC. Generally, CO response was shorter than HC response. This response time variation is apparently a function of the cyclic sampling operation of the unit. The computer "looks" at a 7-second sample of HC and CO and then processes this information for display. Response time will be affected by the sampling rate and frequency.

Unfortunately, hand-controller failure (solder bridge) prevented low altitude gas interference tests from being run, but the same tests at high altitude indicated no response to any of the HC gases. This indicated very high specificity to propane or hexane gases. This high specificity to propane and hexane was not observed for any other HC/CO instrument.

The Autosense was out for repair during the entire vehicle test sequence so no exhaust gas correlation data is available.

The limited data available for the diagnostic tests indicate that, in general, the Autosense showed exhaust gas correlation of better than 2 percent. During the spark plug shorted test, the HC scale showed 10.5 percent full scale error, but showed 2 percent full scale or less error for the balance of the tests.

The Autosense ran 432 hours until failure in the durability tests (corresponding to 387,504 ppm-hours HC exposure and 173 percent-hours CO exposure). The unit experienced 6 days when the shock test produced more than 3 percent full scale readout variation. Average daily span drift was 5.17 percent full scale for HC and 2.76 percent full scale for CO. The unit required 18 filter changes corresponding to 4.2 changes per 100 hours of operation.

During the durability test, it was noted that the flow blockage error code indicated on the remote display/control was not explicit, and its appearance did not necessarily indicate a blocked filter. This same error code could indicate an internal electronic problem. It was also observed during testing that the remote display module was very susceptible to shock. When the hand-held control received a shock or jolt, it sometimes shut down the unit until the instrument start-up was recycled.

The unit failed the durability test in a multi-faceted manner. First, span readings began to creep progressively higher. Later in the testing, the readouts would not zero on air. Finally, the remote display/control indicated a flow error which could not be cleared.

Test data for Autosense 200 Engine Diagnostic and Exhaust Emission Analyzer are shown in Tables 7-66 through 7-70.

Photographs of this instrument are shown in Figures 7-42 through 7-45.

Attachment (1)

Table 7-66. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: **AUTOSENSE 200**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	SINGLE RANGE	HC	8	7	15	7
	"	CO	8	7	15	7

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	SINGLE RANGE	HC	0.5	MALFUNCTION	0	0
	"	CO	0	0	0	0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	SINGLE RANGE	HC	0	-	0	0	0	0
	"	CO	0	0	-	0	0	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 5.2	+ 2.05	- 8.6	- 3.2
	HIGH	HC/CO	70	+ 0.88	+ 0.8	+ 1.08	+ 0.7
	HIGH	HC/CO	100	+ 4.97	+ 4.95	- 0.11	- 0.1
	LOW	HC/CO	5	0.0	0.0	-15.94	- 1.1
	LOW	HC/CO	10	- 3.57	- 0.5	-24.76	- 2.6
	LOW	HC/CO	20	- 4.08	- 0.85	-18.29	- 3.2
CYCLE 2	HIGH	HC/CO	35	INSTRUMENT		-22.04	- 8.2
	HIGH	HC/CO	70	FAILED	-	+ 0.77	+ 0.5
	HIGH	HC/CO	100			+ 0.44	+ 0.4
	LOW	HC/CO	5	NO	DATA	+ 0.45	+ 0.1
	LOW	HC/CO	10			-13.3	- 1.4
	LOW	HC/CO	20			-10.29	- 1.8

Table 7-66. DATA COMPOSITE - LABORATORY TEST (Cont'd) Attachment (1)

AUTOSENSE 200

CYCLE 3	HIGH	HC/CO	35	+ 3.93	+ 1.55	+ 1.08	+ 0.4
	HIGH	HC/CO	70	+ 1.99	+ 1.8	+ 3.45	+ 2.3
	HIGH	HC/CO	100	+ 4.47	+ 4.45	- 0.44	- 0.4
	LOW	HC/CO	5	0.0	0.0	+ 4.35	+ 0.3
	LOW	HC/CO	10	+ 3.57	+ 0.5	-10.48	- 1.1
	LOW	HC/CO	20	+ 3.12	+ 0.65	- 6.29	- 1.1
CYCLE 4	HIGH	HC/CO	35	+ 3.93	+ 1.55	- 4.84	- 1.8
	HIGH	HC/CO	70	+ 0.33	+ 0.3	+ 1.69	+ 1.1
	HIGH	HC/CO	100	+ 3.97	+ 3.95	+ 0.54	+ 0.5
	LOW	HC/CO	5	- 8.33	- 0.5	- 7.25	- 0.5
	LOW	HC/CO	10	- 7.14	- 1.0	-14.29	- 1.5
	LOW	HC/CO	20	- 4.08	- 0.85	- 9.71	- 1.7
HIGH ALTITUDE	HIGH	HC/CO	35	+ 2.66	+ 1.05	- 0.54	- 0.20
	HIGH	HC/CO	70	+ 2.70	+ 2.45	+ 1.85	+ 1.20
	HIGH	HC/CO	100	+ 4.97	+ 4.95	+ 0.44	+ 0.40
	LOW	HC/CO	5	+ 8.33	+ 0.50	+ 4.35	+ 0.30
	LOW	HC/CO	10	+ 3.57	+ 0.50	-11.43	- 1.20
	LOW	HC/CO	20	+ 6.72	+ 0.15	-12.00	- 2.10

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	HC	1750	44	MALFUNCTION	39.5	42.5
	HIGH	CO	8.1	21.5	22.5	23.0	19.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude	SINGLE RANGE	INSTRUMENT		MALFUNCTION			
6750 Feet Altitude	"	0	0	0	0	0	0

Table 7-66. DATA COMPOSITE - LABORATORY TEST (Cont'd)

AUTOSENSE 200

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	SINGLE RANGE	HC	HC CHANNEL BAD	
	115V	"	CO	0	0

Table 7-67. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: **AUTOSENSE 200**

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	SINGLE	HC	6	16	2	4
	RANGE	CO	6	16	2	4

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	SINGLE	HC	0	0	0	0.5
	RANGE	CO	0	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	SINGLE	HC	0	-- --	0	0	0	0
	RANGE	CO	0	0	--	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	SINGLE	HC	0	--	0	0	0	0
	RANGE	CO	0	0	--	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	SINGLE	HC	0	--	0	0	0	0
	RANGE	CO	0	0	--	0	0	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	SINGLE	HC	0	--	0.5	0.5	0	0
	RANGE	CO	0	0	--	0	0	0

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	HC	1724	52.5 sec	55	26	17
		CO	8.1	52.5 sec	42.5	21	12.5

Table 7-67. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

AUTOSENSE 200

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	HIGH	HC/CO	35	+ 4.25	+ 1.65	0	0
	HIGH	HC/CO	70	- 1.46	- 1.34	+ 3.85	+ 2.50
	HIGH	HC/CO	100	+ 3.01	+ 2.95	+ 0.87	+ 0.80
	LOW	HC/CO	35	- 7.56	- 0.45	+ 7.25	+ 0.50
	LOW	HC/CO	70	- 9.42	- 1.30	- 2.86	- 0.[illegible]0
	LOW	HC/CO	100	- 2.68	- 0.55	- 2.86	- 0.50
CYCLE 2	HIGH	HC/CO	35	+ 4.25	+ 1.65	0	0
	HIGH	HC/CO	70	+ 1.34	+ 1.20	+ 1.54	+ 1.0
	HIGH	HC/CO	100	+ 5.05	+ 4.95	+ 1.96	+ 1.80
	LOW	HC/CO	35	+ 9.24	+ 0.55	+ 4.35	+ 0.30
	LOW	HC/CO	70	+ 1.45	+ 0.20	- 4.76	- 0.50
	LOW	HC/CO	100	- 5.11	- 1.05	- 5.14	- 0.90
CYCLE 3	HIGH	HC/CO	35	+ 4.25	+ 1.65	- 3.50	- 1.30
	HIGH	HC/CO	70	+ 0.34	+ 0.30	0	0
	HIGH	HC/CO	100	+ 3.01	+ 2.95	- 1.63	- 1.5
	LOW	HC/CO	35	- 7.56	- 0.45	+ 1.45	+ 0.10
	LOW	HC/CO	70	- 9. 42	- 1.30	- 3.81	- 0.40
	LOW	HC/CO	100	- 2.68	- 0.55	- 5.14	- 0.90
CYCLE 4	HIGH	HC/CO	35	+ 4.25	+ 1.65	- 0.81	- 0.30
	HIGH	HC/CO	70	+ 1.90	+ 1.70	+ 3.69	+ 2.40
	HIGH	HC/CO	100	+ 5.56	+ 5.45	0	0
	LOW	HC/CO	35	- 7.56	- 0.45	+10.15	+ 0.70
	LOW	HC/CO	70	- 2.17	- 0.30	- 1.91	- 0.20
	LOW	HC/CO	100	- 0.24	- 0.05	- 0.57	- 0.10

Table 7-68. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

AUTOSENSE 200

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
LEAN MODE CYCLE 1		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50		OUT	FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				

Table 7-68. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

AUTOSENSE 200

KEY MODE CYCLE #	RANGE PPM/%	SCALE	SPEED	HC		CO	
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1		HC/CO	50			OUT FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 2		HC/CO	50			OUT FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 3		HC/CO	50			OUT FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				
CYCLE 4		HC/CO	50			OUT FOR REPAIR	
		HC/CO	30				
		HC/CO	IDLE				

Table 7-69. DIAGNOSTIC TEST

AUTOSENSE 200

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	2000	HC	1100	1310	- 16.03	- 10.5
	10%	CO	2.14	2.30	- 6.96	- 1.6
NORMAL IDLE	2000	HC	550	576	- 4.51	- 1.3
	10%	CO	2.09	2.25	- 7.11	- 1.6
IGNITION ADVANCE	2000	HC	550	590	- 6.78	- 2.0
	10%	CO	1.98	2.20	- 10.00	- 2.2
IGNITION RETARD	2000	HC	450	479	- 6.05	- 1.45
	10%	CO	1.98	2.10	- 5.71	- 1.2

Table 7-70. DURABILITY TEST DATA

INSTRUMENT: AUTOSENSE 200

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	432
HC EXPOSURE (PPM-HRS.)	387,504
CO EXPOSURE (%-HRS.)	173
NO EXPOSURE (PPM-HRS.)	41,040
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	6
SHOCK TEST FAILURE RATE (Failure/Day %)	22.22
INCIDENCE OF FAILURE IN EACH MODE	
HC ZERO	6
HC SPAN	6
CO ZERO	5
CO SPAN	7
AVERAGE DAILY SPAN DRIFT	
HC%	5.17
CO%	2.76
NO%	--
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER TOTAL PER 100 HRS.	18 4.17
B DRAIN HOSE TOTAL PER 100 HRS.	4 0.93
C REZERO TOTAL PER 100 HRS.	1 0.23
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	-- --
E. OTHER TOTAL PER 100 HRS.	2 0.46

Figure 7-42. AUTOSENSE 200 ENGINE DIAGNOSTIC AND EXHAUST EMISSION ANALYZER (FRONT)

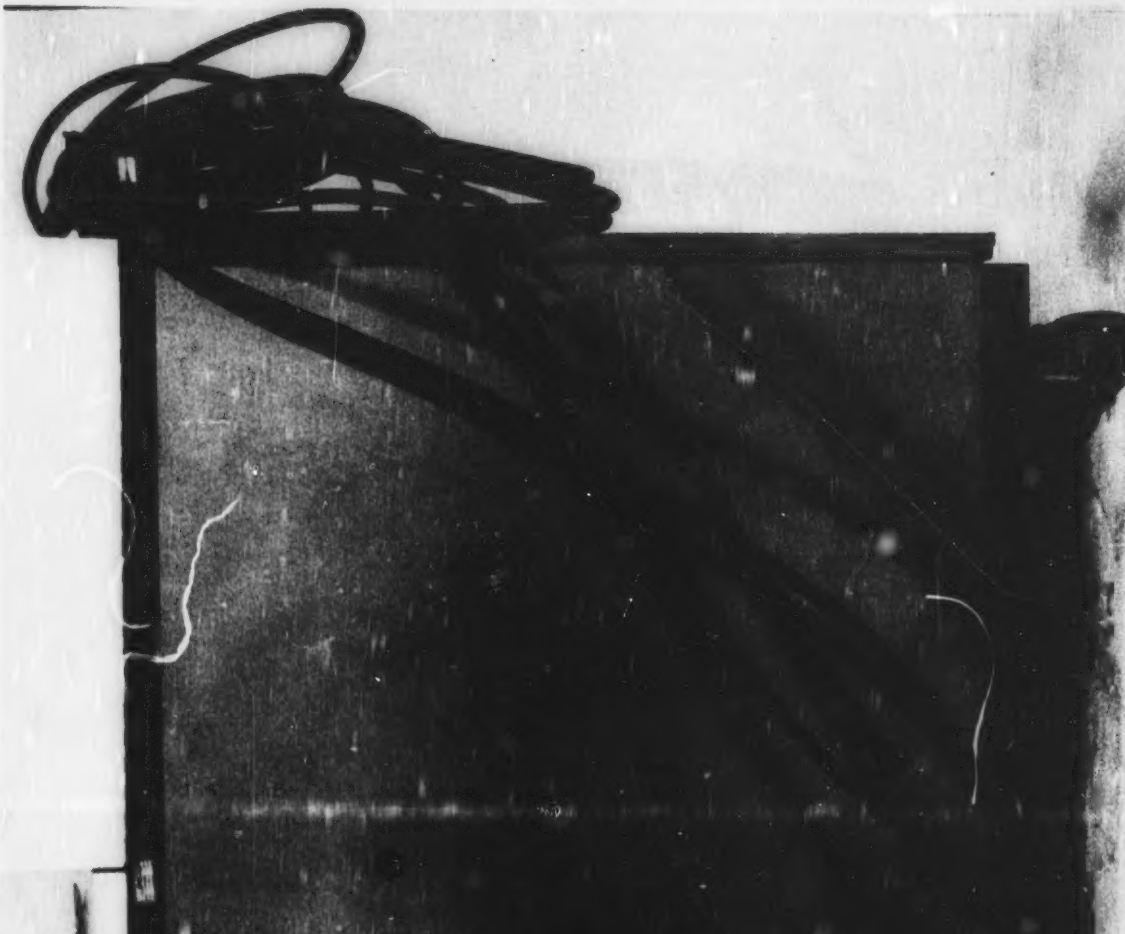

Figure 7-43. AUTOSENSE 200 ENGINE DIAGNOSTIC AND EXHAUST EMISSION ANALYZER (BACK)

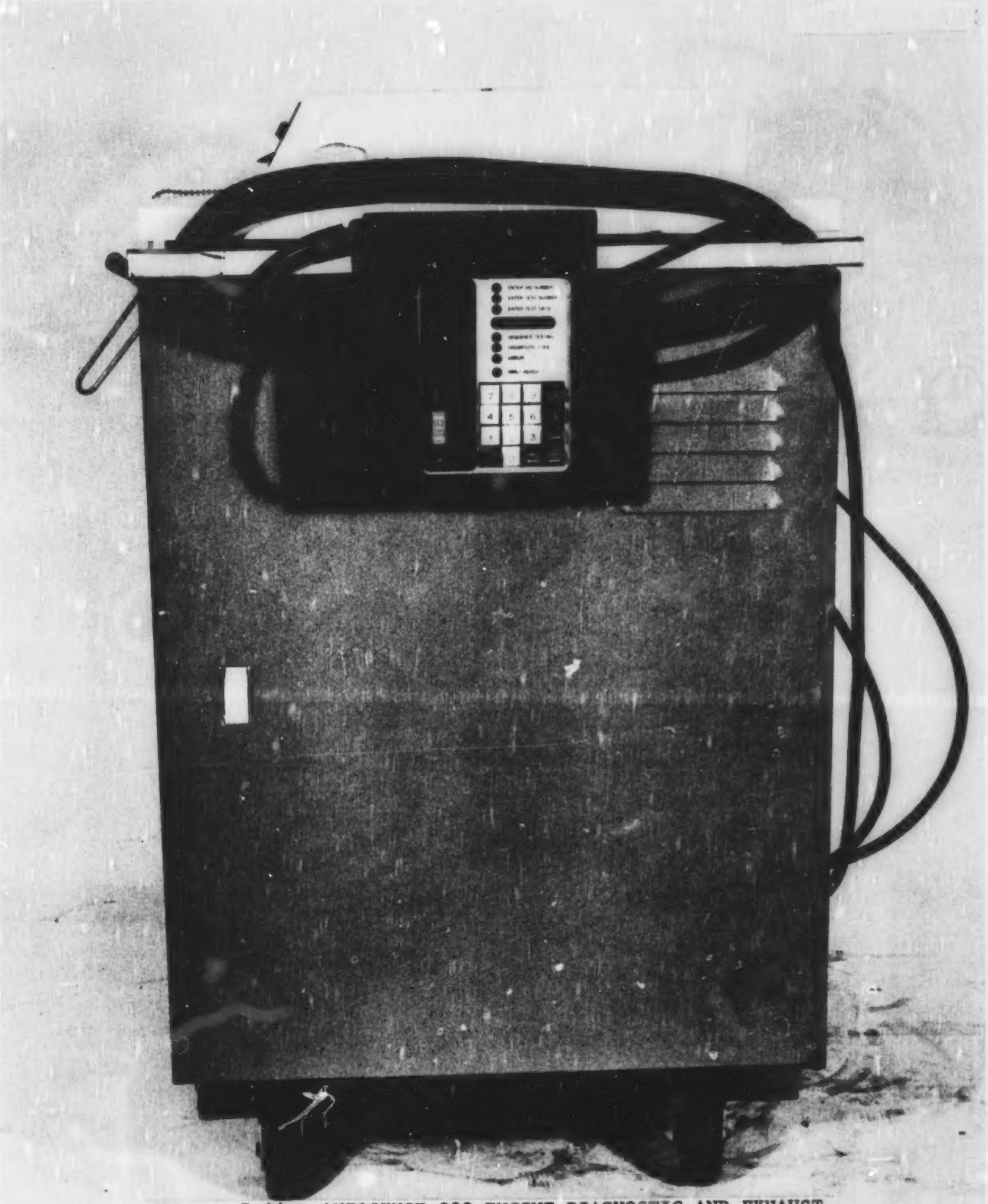

Figure 7-44. AUTOSENSE 200 ENGINE DIAGNOSTIC AND EXHAUST EMISSION ANALYZER (RIGHT SIDE)

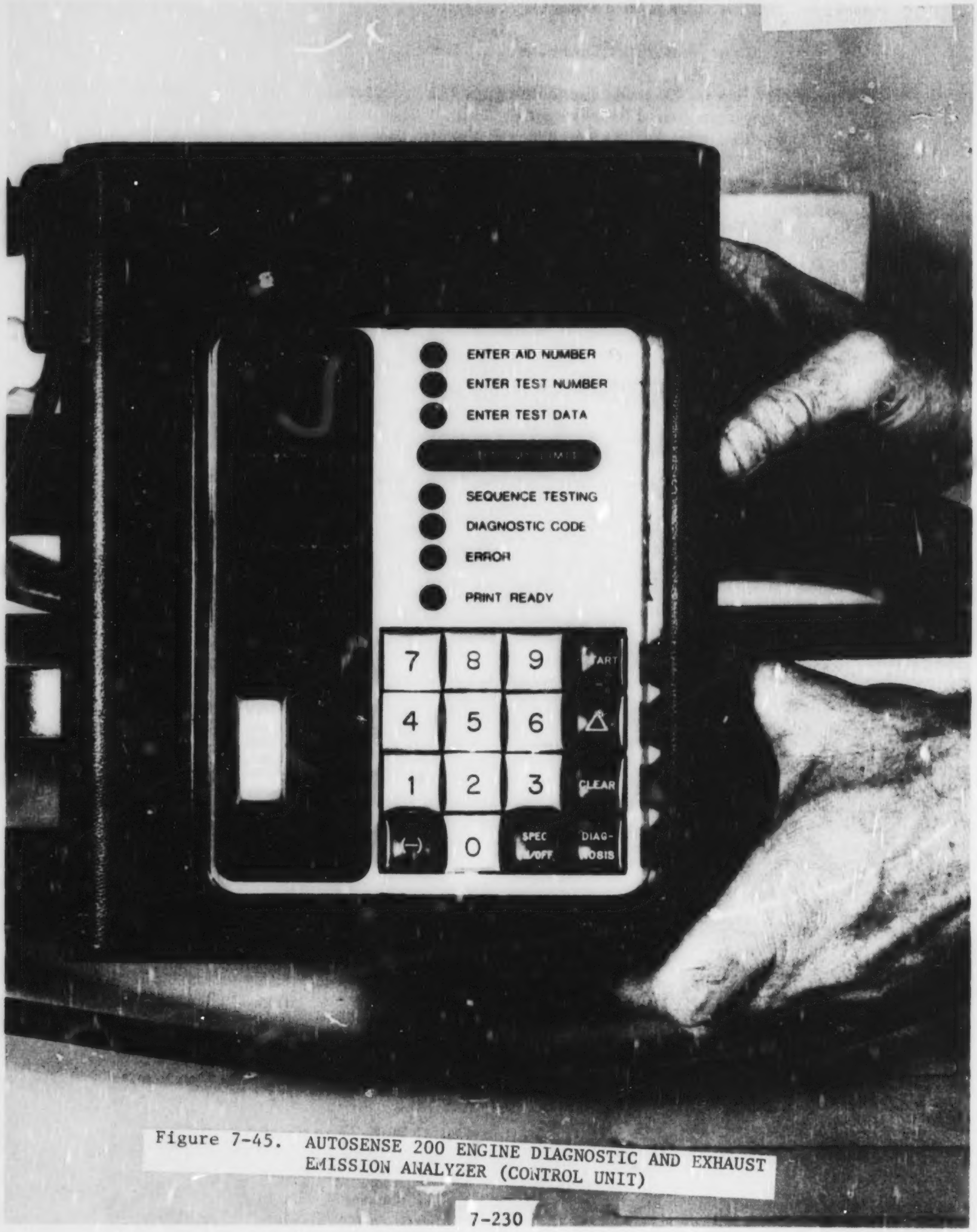
ENTER AID NUMBER
ENTER TEST NUMBER
ENTER TEST DATA
SEQUENCE TESTING
DIAGNOSTIC CODE
ERROR
PRINT READY
7
8
9
START
4
5
6
1
2
3
CLEAR
(−)
0
SPEC ON/OFF
DIAG-NOSIS

Figure 7-45. AUTOSENSE 200 ENGINE DIAGNOSTIC AND EXHAUST EMISSION ANALYZER (CONTROL UNIT)

7.15 HORIBA MEXA 240 INFRARED ANALYZER

Manufacturer - Horiba Instruments, Inc.

Description - NO analyzer configured in a portable cabinet used as a bench top or floor-mounted unit. The unit is not equipped with wheels but is designed with a wide base to enhance stability.

Dimensions -

Height - 25 inches
Width - 9-1/2 inches
Depth - 8 inches
Weight - 27 lbs.

Material of Construction - Sheet steel main frame with sheet aluminum cover.

Color - Grey with silver cover plates.

Mobility - Portable.

Accessories - Sample probe, 8-1/2 foot, sample hose, operator's manual.

Control Package -

Front (Top) Access -
Power On/Off - toggle
Pump/On - toggle
Ranch switch - high/low - toggle
Zero adjust - knob
Span adjust - knob

Front (Bottom) Access -
Dust filter - cartridge
Span gas port
Sample in port
Sample out port

Rear Access -
Fuse
Recorder outputs (+, -)
Recorder output adjust (screw)
Recorder range adjust (screw)

Meters - 3-3/4" , 90° sweep

Ranges - NO - 0-4000 ppm in 100 ppm increments
- 0-1000 ppm in 20 ppm increments

Black characters on white background. The meter was not sensitive to static electricity.

Altitude Compensation - NO provision, gas calibration only.

Probe - 1/4-inch rigid copper tube pinched shut on end and cross-drilled for sample entry. Probe incorporates a prefilter assembly in its base.

Filters and Sample Handling - Prefilter paper cartridge particulate filter in sample probe, small internal water trap, secondary "cigarette filter" type particulate filter, ball type flow indicator.

Cal Gas Inlet - Front panel

Power Requirements - 115 VAC 60HZ 45 watts

Operating Principles - Nondispersive infrared, positive optical filter, dual cell, dual source, gas charged luft-type detector.

Calibration - Gas calibration only using zero and span knobs on front of case.

Operation and Calibration - Simple and straightforward operation and calibration.

Procedure -
1. Turn on and warm up
2. Set zero with front knob
3. Introduce span gas
4. Set span using front span adjust knowb
5. Ready for use

7.15.1 Operational Performance Comments

The unit was equipped with quick release covers to facilitate service access.

In the sampling handling system, this unit had a relatively short sample hose (8-1/2 feet), with a 1/4-inch O.D. tube probe.

This hose was too short for diagnostic work but would be acceptable for inspection operations. The probe incorporated an in-line filter in a small plenum behind the probe and immediately prior to the sample hose. This plenum held a small push-on paper element which was easy to service. On the front panel, the instrument incorporated a cigarette tip type filter for additional protection.

This unit utilized vibrating diaphragm pumps and a small internal water trap. A ball-type flow indicator was recessed in the front panel of this unit and was difficult to see. When it became wet it would stick, indicating high flow. This occurred throughout the durability test.

In the area of the analytical system and display, this unit had a small meter than was extremely difficult to see at a distance. The meter incorporated two scales; 1,000 ppm and 4,000 ppm. For most of the vehicle and durability testing, a lower scale would have been more useful.

In the area of operation and calibration, this unit was by far the most useful of the three NO units. In spite of the flow meter problem and the distance visibility limitation in reading the instrument output meter, the unit was basically simple to operate, highly reliable and appeared to be unaffected by exhaust gases with regard to degradation of operation. Typically, the meter readings were found to be very stable and consistent, showing very little drift.

The Horiba had simple controls; however, calibration was somewhat difficult because the manual spring-loaded valve at the calibration gas port had to be held in by hand during calibration.

In the laboratory tests, this unit showed relatively consistent warm up times of less than 11 minutes. Cold temperature operation required 14 minutes of warm up to reach stabilization.

This unit consistently showed 1 percent full scale or less zero drift under all test conditions.

In the gas interference tests, this unit showed significantly sensitivity to HC and CO and, to a lesser degree, CO_2. CO interference was most significant followed by HC and CO_2.

In the accuracy determination tests, the Horiba 240 was shown to be the overall most accurate instrument tested in this program. The greatest sample gas inaccuracy noted for this instrument at any test point was 1.6 percent full scale. This far extends the consistent demonstrated accuracies of all other test instruments. High altitude tests indicated the same high accuracy. Response time variation ranged from 10 seconds to 33 seconds, indicating a substantial sample transport and analysis time variation.

Voltage fluctuation had no effect on the meter signal level.

In the vehicle tests, the Horiba 240 was easily the most accurate NO instrument tested. In general, the unit showed excellent correlation with the EPA bench. Based upon its laboratory test performance in accuracy determination and response and recovery tests, it is reasonable to assume that large inaccuracies noted in the vehicle tests could be related to response time variation and, thus, sample time correlation.

In the durability tests, the Horiba 240 survived to the conclusion of testing with no obvious or apparent problems. No obvious degradation in analysis quality was noted nor did the analyzer experience any malfunctions during the tests.

This unit required frequent changing of the in-line filter, but its twist-lock housing made this operation very quick and easy. The cigarette tip filter also required relatively frequent service but, again, this service was very quick and easy. This unit demonstrated an average daily span drift of 2.84 percent full scale.

Filter servicing was required 31 times during testing. Test duration was 960 hours (114,240 ppm NO-hours). The filter service requirement was 3.7 service per 100 hours of operation.

In general, this NO analyzer was judged to be the only unit that meets the specific requirements of I/M analysis.

Test data for Horiba Mexa 240 Infrared Analyzer are shown in Tables 7-71 through 7-75.

Photographs of this instrument are shown in Figures 7-46, 7-47, and 7-48.

Table 7-71. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: HORIBA MEXA 240

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	6	5	14	6

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	NO	0	0.5	0.3	0.6

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	1.5	0.3	2.8	0	-	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO			
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	+ 2.04	+ 0.7		
	LOW	NO	70	- 0.13	- 0.1		
	LOW	NO	100	- 1.03	- 1.0		
	HIGH	NO	35	0.0	0.0		
	HIGH	NO	70	- 0.21	- 0.13		
	HIGH	NO	100	+ 0.26	+ 0.25		
CYCLE 2	LOW	NO	35	+ 0.29	+ 0.1		
	LOW	NO	70	+ 0.26	+ 0.2		
	LOW	NO	100	+ 0.52	+ 0.5		
	HIGH	NO	35	- 0.99	- 0.25		
	HIGH	NO	70	0.0	0.0		
	HIGH	NO	100	+ 0.78	+ 0.75		

Attachment (1)

Table 7-71. DATA COMPOSITE - LABORATORY TEST (Cont'd)

HORIBA MEXA 240

NO

CYCLE 3	LOW	NO	35	+ 4.65	+ 1.6		
	LOW	NO	70	+ 0.13	+ 0.1		
	LOW	NO	100	- 0.52	- 0.5		
	HIGH	NO	35	+ 0.5	+ 0.13		
	HIGH	NO	70	0.0	0.0		
	HIGH	NO	100	+ 0.26	+ 0.25		
CYCLE 4	LOW	NO	35	+ 1.74	+ 0.6		
	LOW	NO	70	+ 0.39	+ 0.3		
	LOW	NO	100	- 0.41	- 0.4		
	HIGH	NO	35	0.0	0.0		
	HIGH	NO	70	- 0.21	- 0.13		
	HIGH	NO	100	+ 0.78	+ 0.75		
HIGH ALTITUDE	LOW	NO	35	+ 1.74	+ 0.60		
	LOW	NO	70	+ 0.26	+ 0.20		
	LOW	NO	100	- 0.10	- 0.10		
	HIGH	NO	35	0.0	0.0		
	HIGH	NO	70	- 0.21	- 0.13		
	HIGH	NO	100	+ 0.26	+ 0.25		

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	NO	3400	20.5	34.3	28.9	20.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm					
		287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude							
6750 Feet Altitude							

Table 7-71. DATA COMPOSITE - LABORATORY TEST (Cont'd)

HORIBA MEXA 240

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	NO	0	0

Table 7-72. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: HORIBA MEXA 240

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	8	16	6	11

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	0	0	1.0	0

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	3.5	2.1	6.2	1.0	-	2.0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	1.5	0	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	1.0	2	2.8	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0.6	2.2	3.0	1.0	-	0.7

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	NO	3400	33.5	10.5	11.25	19

HORIBA MEXA 240

Table 7-72. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO			
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	+3.20	+1.10		
	LOW	NO	70	+0.90	+0.70		
	LOW	NO	100	0	0		
	HIGH	NO	35	+0.49	+0.13		
	HIGH	NO	70	0	0		
	HIGH	NO	100	-0.52	-0.50		
CYCLE 2	LOW	NO	35	-1.16	-0.40		
	LOW	NO	70	-2.31	-1.80		
	LOW	NO	100	-1.55	-1.50		
	HIGH	NO	35	0	0		
	HIGH	NO	70	+2.27	+1.37		
	HIGH	NO	100	-0.78	-0.75		
CYCLE 3	LOW	NO	35	+3.20	+1.10		
	LOW	NO	70	-0.39	-0.30		
	LOW	NO	100	-0.52	-0.50		
	HIGH	NO	35	0	0		
	HIGH	NO	70	+2.27	+1.36		
	HIGH	NO	100	+0.52	+0.50		
CYCLE 4	LOW	NO	35	+1.74	+0.60		
	LOW	NO	70	-0.39	-0.30		
	LOW	NO	100	-0.52	-0.50		
	HIGH	NO	35	0	0		
	HIGH	NO	70	+2.27	+1.38		
	HIGH	NO	100	-1.03	-1.0		

Table 7-73. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

HORIBA MEXA 240

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO	
				% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	4000	NO	50	- 7.72	- 4.63
	4000	NO	30	- 9.47	- 3.4
	1000	NO	IDLE	+ 1.78	+ 0.21
CYCLE 2	4000	NO	50	- 3.04	- 1.73
	4000	NO	30	- 3.57	- 1.25
	1000	NO	IDLE	+ 4.33	+ 0.51
CYCLE 3	4000	NO	50	- 2.98	- 1.65
	4000	NO	30	- 4.13	- 1.4
	1000	NO	IDLE	- 3.79	- 0.48
CYCLE 4	4000	NO	50	- 13.76	- 8.18
	4000	NO	30	- 16.43	- 5.65
	1000	NO	IDLE	- 10.94	- 1.29
LEAN MODE CYCLE 1	4000	NO	50	- 7.58	- 4.33
	4000	NO	30	- 8.77	- 3.13
	1000	NO	IDLE	- 0.65	- 0.08
CYCLE 2	4000	NO	50	- 3.82	- 2.13
	4000	NO	30	- 4.13	- 1.4
	1000	NO	IDLE	- 4.68	- 0.58
CYCLE 3	4000	NO	50	- 4.89	- 2.73
	4000	NO	30	- 5.4	- 1.83
	1000	NO	IDLE	- 10.09	- 1.13
CYCLE 4	4000	NO	50	- 5.97	- 3.34
	4000	NO	30	- 6.66	- 2.3
	1000	NO	IDLE	- 24.64	- 3.27

Table 7-73. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

HORIBA MEXA 240

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO	
				% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	4000	NO	50	- 4.87	- 2.75
	4000	NO	30	- 5.5	- 1.95
	1000	NO	IDLE	+ 5.17	+ 0.61
CYCLE 2	4000	NO	50	- 2.65	- 1.5
	4000	NO	30	- 3.44	- 1.18
	1000	NO	IDLE	+ 8.7	+ 1.0
CYCLE 3	4000	NO	50	- 1.7	- 0.95
	4000	NO	30	- 4.69	- 1.6
	1000	NO	IDLE	+ 6.02	+ 0.71
CYCLE 4	4000	NO	50	- 1.45	- 0.83
	4000	NO	30	- 5.21	- 1.8
	1000	NO	IDLE	+ 24.58	+ 2.17

Table 7-74. DIAGNOSTIC TEST

HORIBA MEXA 240

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	1000	NO	110	147	- 25.17	- 3.7
NORMAL IDLE	1000	NO	112	147	- 23.81	- 3.5
IGNITION ADVANCE	1000	NO	115	132	- 12.88	- 1.7
IGNITION RETARD	1000	NO	118	132	- 10.61	- 1.4

Table 7-75. DURABILITY TEST DATA

INSTRUMENT: HORIBA MEXA 240

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	960
HC EXPOSURE (PPM-HRS.)	809,280
CO EXPOSURE (%-HRS.)	528
NO EXPOSURE (PPM-HRS.)	114,240
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	NOT APPLICABLE
SHOCK TEST FAILURE RATE (Failure/Day %)	NOT APPLICABLE
INCIDENCE OF FAILURE IN EACH MODE	NOT APPLICABLE
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	
HC%	--
CO%	--
NO%	2.84
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	31
PER 100 HRS.	3.73
B DRAIN HOSE	
TOTAL	--
PER 100 HRS.	--
C REZERO	
TOTAL	36
PER 100 HRS.	3.75
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	1
PER 100 HRS.	0.1

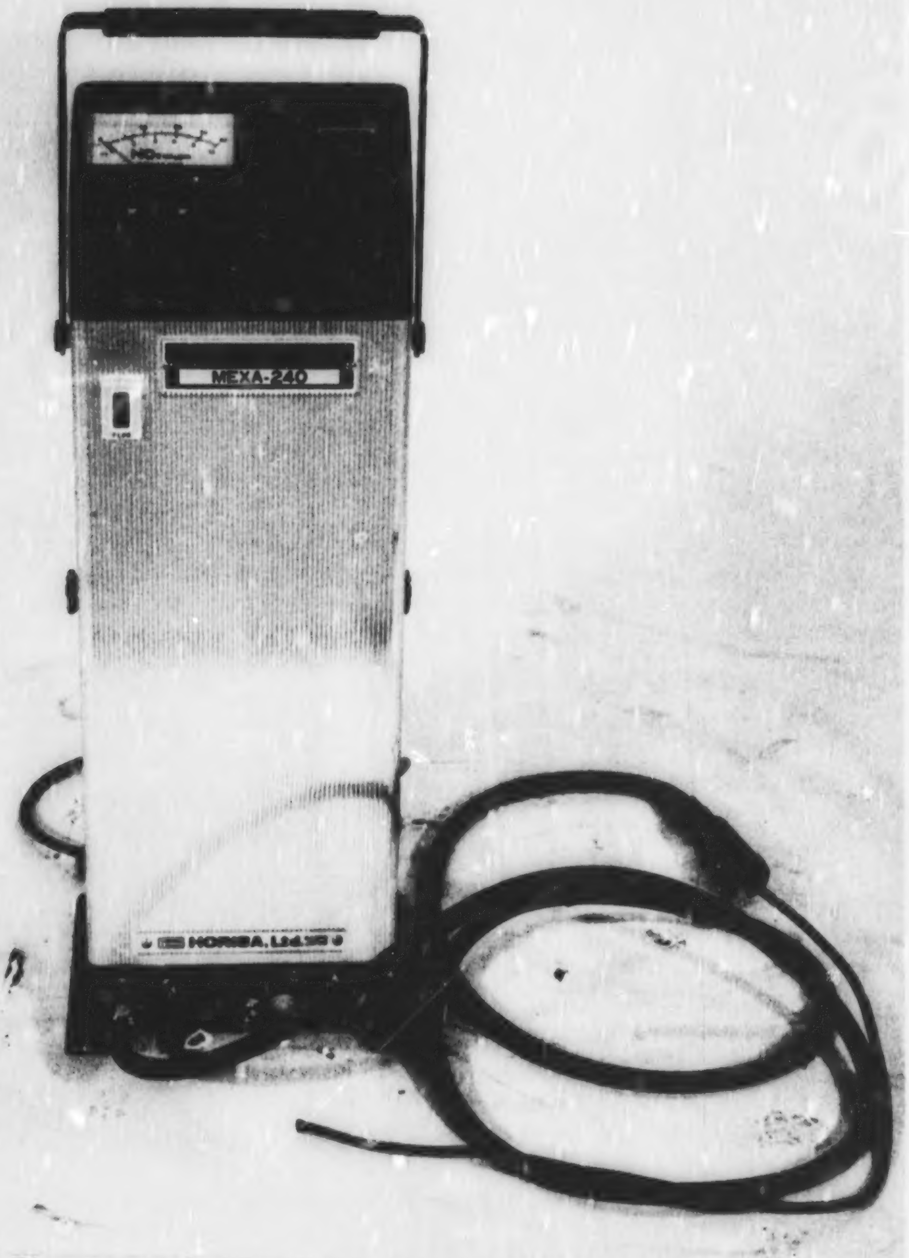
MEXA-240
HORIBA, Ltd.

Figure 7-46. HORIBA MEXA 240 INFRARED ANALYZER

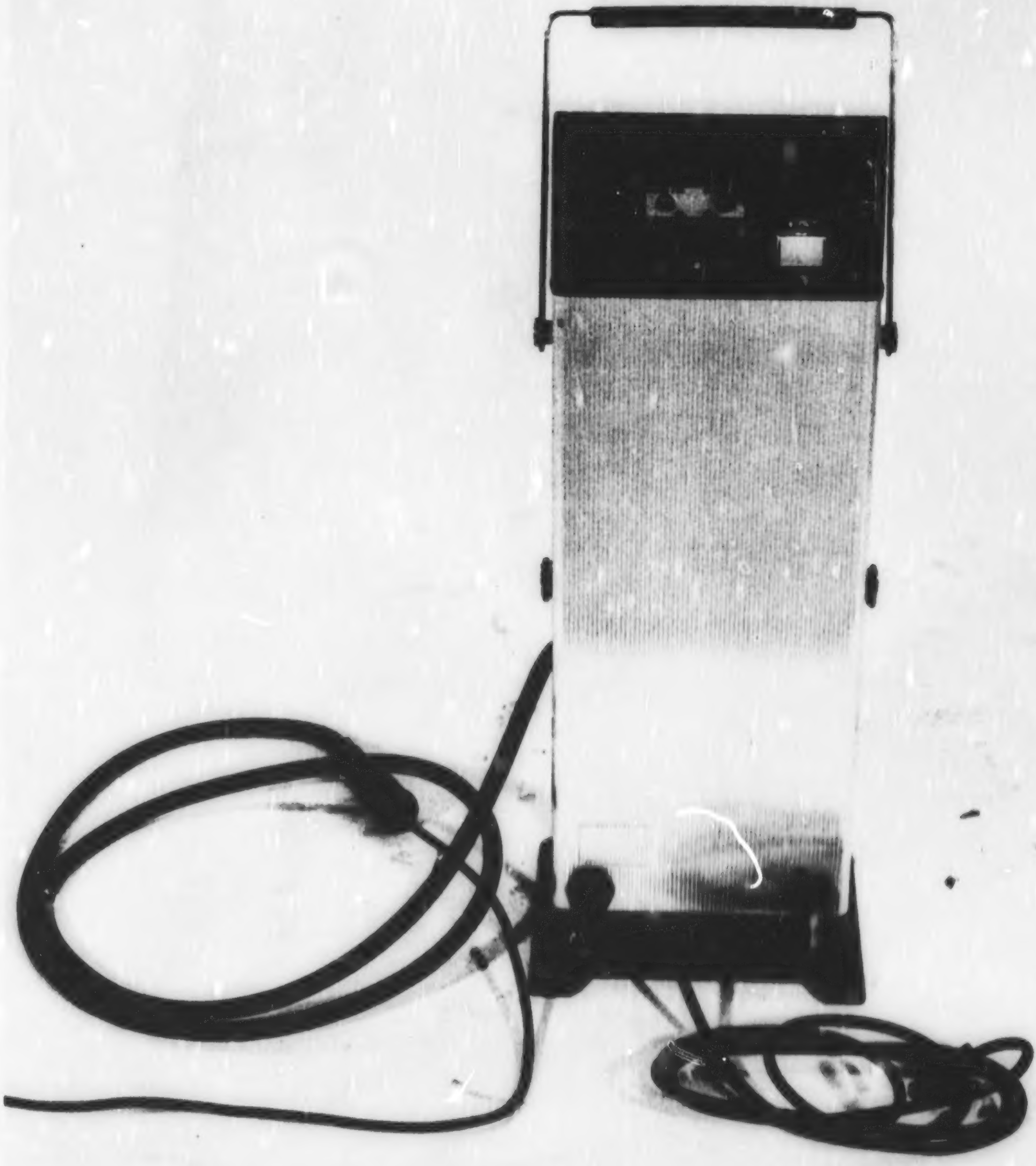

Figure 7-47. HORIBA MEXA 240 INFRARED ANALYZER (BACK)

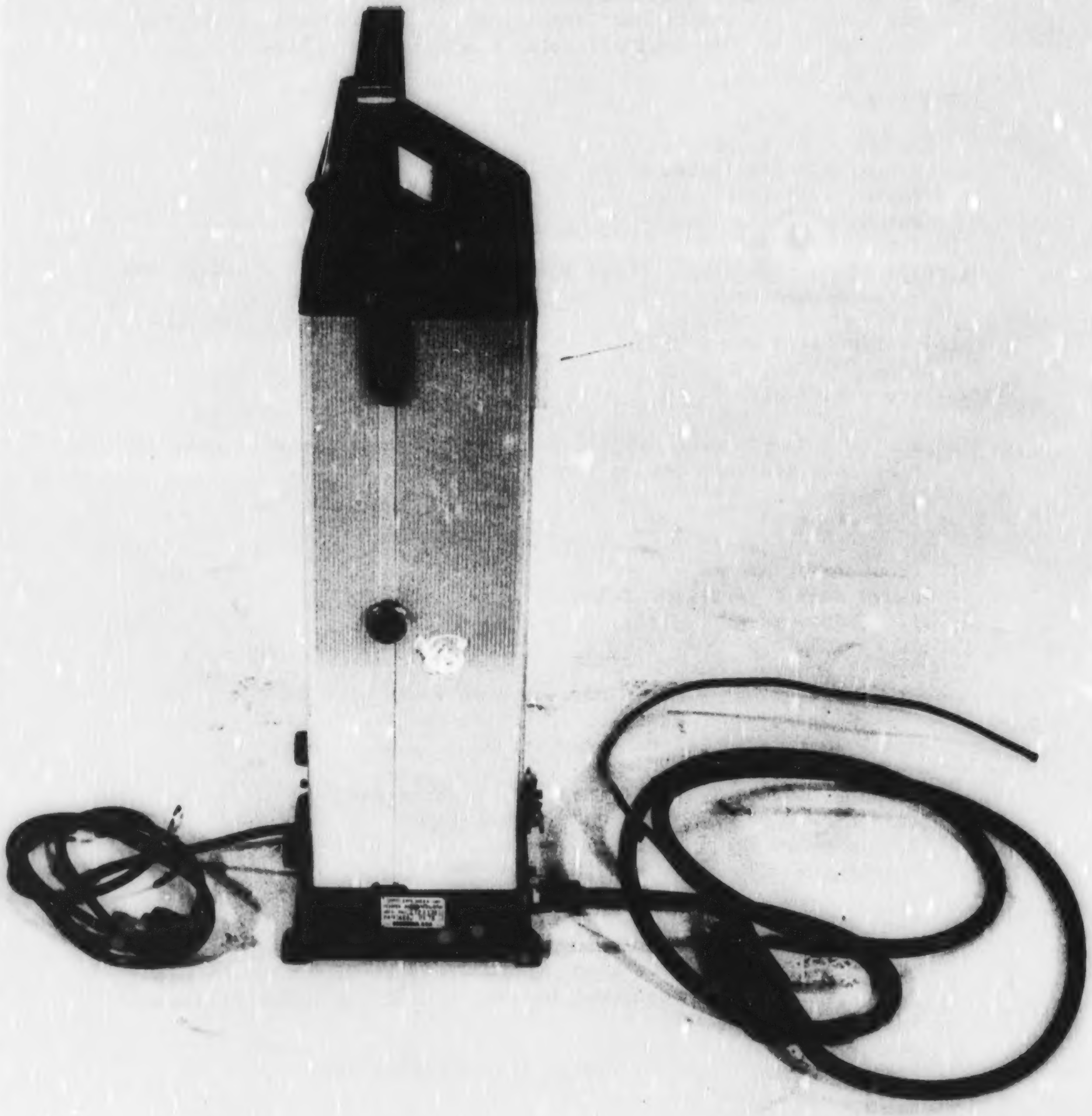

Figure 7-48. HORIBA MEXA 240 INFRARED ANALYZER (LEFT SIDE AND PROBE)

7.16 THERMO ELECTRON 8A NO ANALYZER

Manufacturer - Thermo Electron Corporation

Description - Portable chemiluminescent NO analyzer configured as a bench top unit. All sample handling equipment incorporated in or on analyzer case. No optional cart or wheels available.

Dimensions -

Height - 10 inches
Width - 8-1/4 inches
Depth - 16-inches
Weight - 32-1/2 lbs.

Material of Construction - Sheet metal case and face plate welded and screwed together.

Color - Blue with white front.

Mobility - Portable

Accessories - Sample probe with water trap/prefilter, sample hose (10 feet long 1/4-inch Teflon tube), operator's manual.

Control Package -

Front Panel Access -
Range switch (three-position)
1. 500 ppm
2. 1,000 ppm
3. 5,000 ppm
Zero adjust - multi turn vernier scale with lock
Span adjust - multi turn vernier scale with lock
Power on - Lighted push button

Pressure Gauges (2) - Linear scale with needle
1. Air
2. Sample
Bypass flowmeter - adjustable

Rear Access -
Sample flow regulator - knob
Air flow regulator - knob
Pump vent switch - push button
Inlet air dryer
Sample port
Exhaust outlet charcoal filter (for excess ozone)
5 amp fuse cartridge

Meters - 5-inch, 100° sweep
Black characters on white background.

Three Ranges - NO - 0-500 ppm in 10 ppm increments
0-1000 ppm in 20 ppm increments
0-5000 ppm in 100 ppm increments

The meter was not sensitive to static electricity.

Altitude Compensation - None, gas calibration only at site of test.

Probe - 1/4-inch OD stainless steel tubing, 3 feet long with cooling coil at probe vase. A paper filter cartridge is contained in the probe-mounted water trap. Probe is equipped with a handle.

Filter and Sample Handling - Primary particulate (paper cartridge) filter in probe handle. Internal water trap.

Cal Gas Inlet - Sample port is used

Power Requirements - 115 VAC 60HZ 224 watts

Operating Principles - Chemiluminescent reaction of NO and ozone employing a pulsed ozonator method to generate ozone from dry air.

Calibration - Gas calibration on each range of operation with electronic reference calibration check using "check" button. Reference calibration is based upon results of gas calibration so gas calibration must be performed first.

Operation and Calibration - Moderately difficult with many critical pressure and flow setting requirements, in addition to span and zero adjustments. Operation and calibration requirements are judged to be more difficult than the level deemed acceptable for I/M instrumentation and diagnostic application.

7.16.1 Operational Performance Comments

The mechanical package for this unit consisted of a relatively small bench top cabinet, which incorporated all sample handling equipment. Everything that was required was included in one package. The sample pickup system consisted of a 1/4-inch diameter rigid probe with a 10-foot sample hose. The instrument incorporated an internal water trap, which appeared to be ineffective for the conditions of this evaluation testing.

The operator's manual recommends additional externally plumbed cold traps and/or particulate filters if the sample contained excessive moisture or particulate matter. Based upon test results, the unit would require at least an additional cold trap to function in an I/M test environment.

This analyzer used the chemiluminescence method for sample detection.

In sample gas analysis, correlation between NDIR and chemiluminescence methods could be expected to be relatively poor. In fact, this instrument demonstrated very good accuracy and correlation except on the highest scale (0 to 5,000).

The display on this instrument a single 5-1/2-inch meter that demonstrated slow response to automotive exhaust and generally unstable readings. It was relatively easy to read at short distances. After using this instrument, it was agreed that it was not totally applicable for garage operation or automotive inspection and maintenance in its present form.

The adjustments for this instrument seemed to work backwards, giving changes in readings that were the reverse of those anticipated. The response to the adjustment controls was very delayed and hard to anticipate.

In the area of maintenance, it was noted that this unit appeared to be unreliable in this application, as its performance could not be accurately predicted. This unit appears to be more a laboratory-type unit not specificially intended for the automotive environment of this test.

The unit failed to calibrate during the high temperature cycle of the laboratory test sequence. It required return to the factory for repair. The high voltage transformer was found to be defective. During the laboratory repeatability test, the readings were extremely intermittent and generally unreliable. After this problem was encountered the local service representative was notified. No successful diagnosis was ever made and no further repair was attempted.

This intermittent problem of instability caused the unit to miss many of the tests in the vehicle test phase and the entire durability test phase.

In the durability tests, this unit showed no complete inability to handle the high moisture content of the exhaust gas. Additional cold traps or auxiliary sample handling accessories are definitely needed to use this instrument in an I/M application.

Test data for Thermo Electron 8A NO Analyzer are shown in Tables 7-76 through 7-80.

Photographs of this instrument are shown in Figures 7-49, 7-50, and 7-51.

Table 7-76. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: THERMO ELECTRON 8A

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	15	20	22	12

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	NO	1.0	MALFUNCTION	0.4	0.8

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	0	0	-	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO			
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	+ 2.27	+ 0.8		
	LOW	NO	70	+ 0.58	+ 0.4		
	LOW	NO	100	- 1.0	- 1.0		
	HIGH	NO	35	+20.0	+ 7.0		
	HIGH	NO	70	- 4.39	- 3.4		
	HIGH	NO	100	-	-		
CYCLE 2	LOW	NO	35	INSTRUMENT	FAILED		
	LOW	NO	70				
	LOW	NO	100	NO	DATA		
	HIGH	NO	35				
	HIGH	NO	70				
	HIGH	NO	100				

Table 7-76. DATA COMPOSITE - LABORATORY TEST (Cont'd)
THERMO ELECTRON 8A

CYCLE 3	LOW	NO	35	+ 2.27	+ 0.8		
	LOW	NO	70	+ 0.87	+ 0.6		
	LOW	NO	100	- 1.2	- 1.2		
	HIGH	NO	35	+22.86	+ 8.0		
	HIGH	NO	70	- 1.81	- 1.4		
	HIGH	NO	100	-	-		
CYCLE 4	LOW	NO	35	+ 0.57	+ 0.2		
	LOW	NO	70	+ 1.45	+ 1.0		
	LOW	NO	100	+ 0.4	+ 0.4		
	HIGH	NO	35	+22.86	+ 8.0		
	HIGH	NO	70	+ 3.36	+ 2.6		
	HIGH	NO	100	-	-		
HIGH ALTITUDE	LOW	NO	35	+ 1.14	+ 0.4		
	LOW	NO	70	+ 1.74	+ 0.6		
	LOW	NO	100	+ 0.40	+ 0.4		
	HIGH	NO	35	+22.84	+ 8.0		
	HIGH	NO	70	- 1.16	- 0.9		
	HIGH	NO	100	-	-		
	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	NO	3400	43.5	INSTRUMENT FAILED NO DATA	43.8	47.5
HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude							
6750 Feet Altitude							

Table 7-76. DATA COMPOSITE - LABORATORY TEST (Cont'd)

THERMO ELECTRON

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	NO	INSTRUMENT MALFUNCTION	

Table 7-77. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: THERMO ELECTRON 8A

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	MALFUNCTION	33	9	11

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	8.0	0.8	0.4	0

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	0	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	0	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	0	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	38.0	0	-	0

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	NO	3400	41	13.5	12	25.5

THERMO ELECTRON 8A

Table 7-77. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO			
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	+5.11	+1.80		
	LOW	NO	70	+3.20	+2.20		
	LOW	NO	100	-0.40	-0.40		
	MEDIUM	NO	35	+10.47	+3.60		
	MEDIUM	NO	70	-1.03	-0.80		
	MEDIUM	NO	100	-3.09	-3.0		
CYCLE 2	LOW	NO	35	+7.95	+2.80		
	LOW	NO	70	+1.74	+1.20		
	LOW	NO	100	-7.19	-7.20		
	MEDIUM	NO	35	+6.10	+2.10		
	MEDIUM	NO	70	+9.25	+7.20		
	MEDIUM	NO	100	0	0		
CYCLE 3	LOW	NO	35	-9.09	-3.20		
	LOW	NO	70	+2.62	+1.80		
	LOW	NO	100	-5.19	-5.20		
	MEDIUM	NO	35	+13.37	+4.60		
	MEDIUM	NO	70	-8.10	-6.30		
	MEDIUM	NO	100	-5.15	-5.00		
CYCLE 4	LOW	NO	35	+0.57	+0.20		
	LOW	NO	70	+1.16	+0.80		
	LOW	NO	100	-5.19	-5.20		
	MEDIUM	NO	35	+9.01	+3.10		
	MEDIUM	NO	70	-5.78	-4.30		
	MEDIUM	NO	100	-14.43	-14.0		

Table 7-78. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

THERMO ELECTRON 8A

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO % ERROR ABSOLUTE	 % ERROR FS
STANDARD MODE CYCLE 1		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 2		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 3		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 4		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
LEAN MODE CYCLE 1		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 2		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 3		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 4		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		

Table 7-78. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

THERMO ELECTRON 8A

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO % ERROR ABSOLUTE	NO % ERROR FS
RICH MODE CYCLE 1		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 2		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 3		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		
CYCLE 4		NO	50	OUT FOR REPAIR	
		NO	30		
		NO	IDLE		

Table 7-79. DIAGNOSTIC TEST

THERMO ELECTRON 8A

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED			INOPERATIVE			
NORMAL IDLE			INOPERATIVE			
IGNITION ADVANCE			INOPERATIVE			
IGNITION RETARD			INOPERATIVE			

Table 7-80. DURABILITY TEST DATA

INSTRUMENT: THERMO ELECTRON 8A

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	NO TEST DATA
TIME TO FAILURE (HRS.)	
HC EXPOSURE (PPM-HRS.)	
CO EXPOSURE (%-HRS.)	
NO EXPOSURE (PPM-HRS.)	
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	NOT APPLICABLE
SHOCK TEST FAILURE RATE (Failure/Day %)	NOT APPLICABLE
INCIDENCE OF FAILURE IN EACH MODE	NOT APPLICABLE
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	NO TEST DATA
HC%	
CO%	
NO%	
INSTRUMENT SERVICE REQUIREMENTS	NO TEST DATA
A CHANGE FILTER TOTAL PER 100 HRS.	
B DRAIN HOSE TOTAL PER 100 HRS.	
C REZERO TOTAL PER 100 HRS.	
D. SAMPLING SYSTEM TOTAL PER 100 HRS.	
E. OTHER TOTAL PER 100 HRS.	

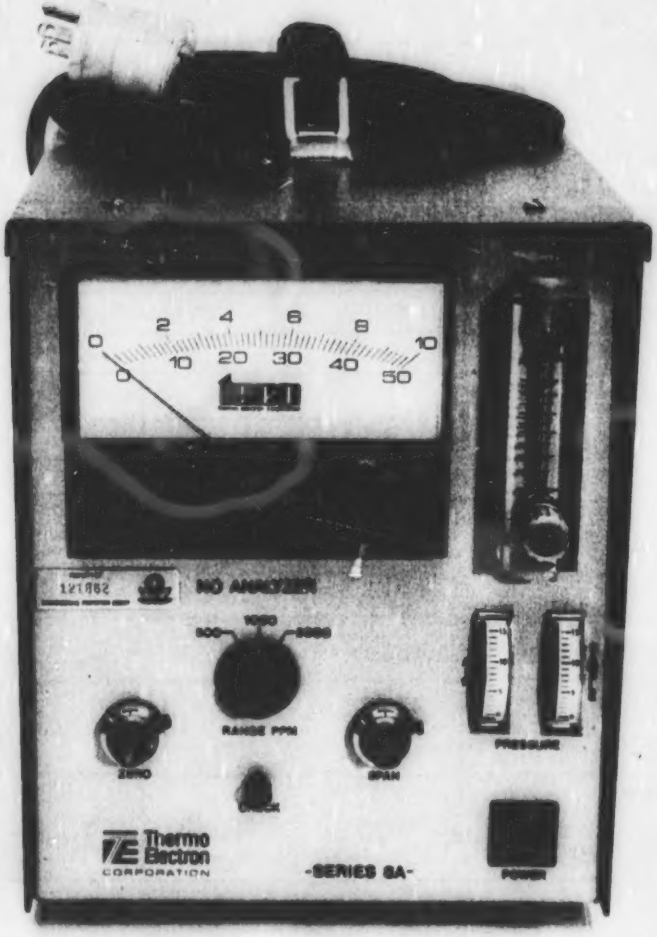
0
2
4
6
8
10
0
10
20
30
40
50
121862
NO ANALYZER
500
1000
2000
RANGE PPM
ZERO
SPAN
CHECK
PRESSURE
POWER
Thermo Electron CORPORATION
-SERIES 8A-

Figure 7-49. THERMO ELECTRON 8A NO ANALYZER

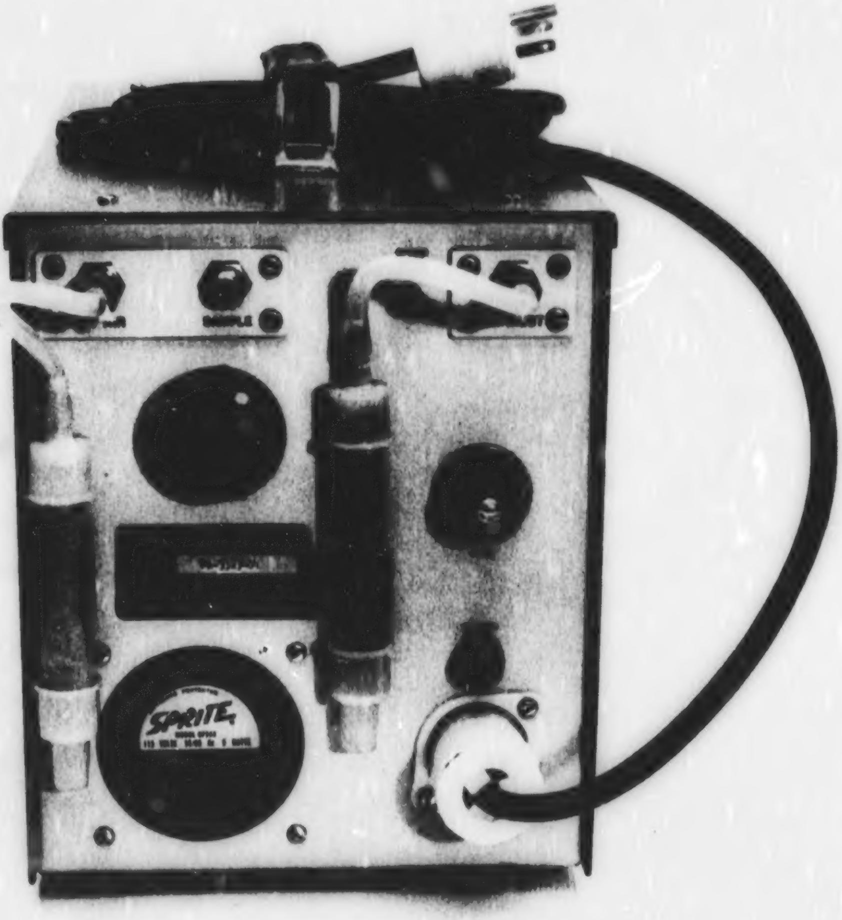
SAMPLE
SPRITE

Figure 7-50. THERMO ELECTRON 8A NO ANALYZER (BACK)

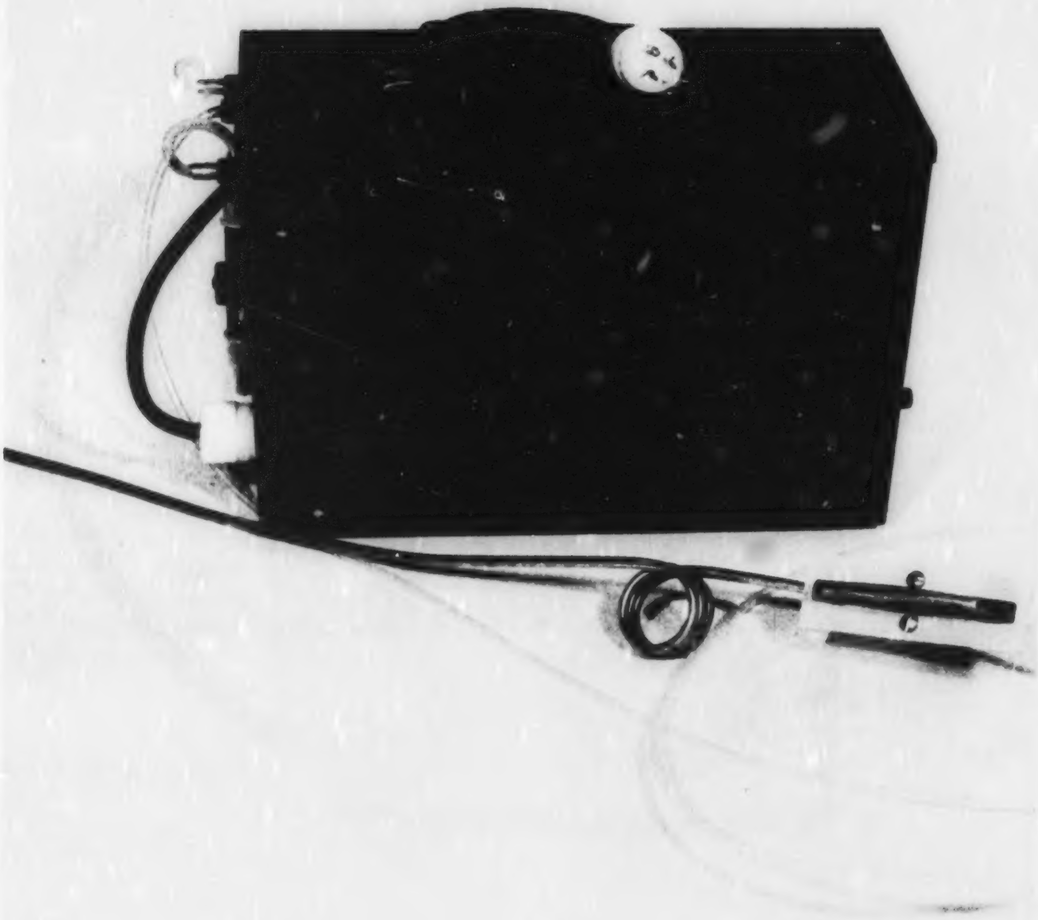

Figure 7-51. THERMO ELECTRON 8A NO ANALYZER (RIGHT SIDE AND PROBE)

7.17 IBC N322 N/SC-400 NITROGEN OXIDE ANALYZER

Manufacturer - International Bio Physics Corporation (Selesco)

Description - NO analyzer using specific eletro-chemical detection method. The analyzer is configured as a portbale bench top unit. In this application, it is used with a portable sample/control module. (Model SC-400).

Dimensions -

Analyzer -
Height - 6-1/2 inches
Width - 12-3/4 inches
Depth - 12-3/4 inches
Weight - 14 lbs.

Sample/Control Module -
Height - 8 inches
Width - 7-1/2 inches
Depth - 11 inches
Height - 12-3/4 lbs

Material of Construction - Sheet metal cabinets and face panels welded and screwed together.

Color -

Analyzer - Brown with tan face
Sampler - Blue with light blue face

Mobility - Both modules are portable

Accessories - Sample probe, 15-foot sample hose, operator's manual.

Control Package -

Analyzer Front Access - Mode switch (six positions)
1. Calibrate NO
2. Calibrate NO_x
3. Sample NO_x
4. Sample NO_2
5. Sample NO
NO null adjust - multi turn pot with lock
NO calibrate - multi turn pot with lock
NO_2 null adjust - multi turn pot with lock
NO_2 calibrate - multi turn pot with lock
NO_x ratio trim - screw
NO ratio trim - screw
Analyzer power on - rocks switch
Heater Power on - rocks switch

Rear Access -
Analog output plug (NO_x-NO)
Analog output plug (NO_2)
NO_x - NO analog adjust (screw)
NO_2 analog adjust (screw)
NO_x outlet port
NO_x inlet port
NO_2 outlet port
NO_2 inlet port
1/4 analyzer fuse
2A heater fuse

Sampler - Control Module Front Access -
Mode switch (cal gas) (three-position)
1. Cal gas-B
2. Cal gas-A
3. Purge

Mode Switch (sample) (three-position)
1. Sample-B
2. Sample-A
3. Purge

Cal Gas Flow Controls (2) -
1. Cal gas-A
2. Cal gas-B

Flow meter (adjustable)
Power switch (toggle)
Power on light

Rear Access -
Sample and cal gas ports (9)
1. P-4
2. P-3
3. P-2
4. To analyzer
5. Cal gas-A
6. P-1
7. Sample-A
8. Cal gas-B
9. Sample-B

Meters - 4-1/2", 100° sweep (one meter)
Black characters on white background

Three ranges for each sample mode (NO, NO_2, NO_x)

0-500 ppm in 5 ppm increments
0-1000 ppm in 10 ppm increments
0-5000 ppm in 50 ppm increments

The meter was only slightly sensitive to static electricity.

Altitude Compensation - None. Gas calibration required at test site.

Probe - 1/2-inch diamter copper tube pinched closed on end with cross-drilled holes for sample entrance. Probe has handle and tail pipe clamp.

Filters and Sample Handling - Glass fiber-filled tube used for particulate filtering. Water drop-out trap with no drain. Both units enclosed in sampler/control module.

Cal Gas Inlet - Read of sampler/control module.

Power Requirements - Analyzer 115 VAC 60HZ 2 1/4 amp Sampler 115 VAC 60HZ 2 amp.

Operating Principles - Specific electro-chemical analysis using "Faristor" cartridges mounted in rear of analyzer cabinet.

Calibration - Gas calibration only utilizing sampler/control module. Calibration is time-consuming and involved.

Operation and Calibration - The operation and calibration of this instrument required manipulation and interpretation of the switching and control module which was much too complex for an I/M application. The IBC has both NO and NO_x capability, which adds more complexity. The sample detection technique employed by this analyzer uses a special sensor which provides an electrical signal output from catalytic oxidation of the gas sample.

7.17.1 Operational Performance Comments

This unit was found to be a laboratory-type instrument, with a separate module incorporating switching valves and a flow meter. It was determined after initial testing that the intent of this instrument was probably not consistent with an automotive I/M application. The unit allows detection of NO, NO_2, and NO_x in ranges of 500, 1,000, and 5,000 ppm utilizing two specific Faristor modules.

In the sample handling area, this unit utilized a copper tube probe with black tygon tubing for sample hose. The instrument used glass fibers as a filter, and a simple manually-drained plenum in the probe for water removal.

In general, this unit had stable meter readings. However, the NO concentration values indicated on the meter were not reliable due to oxides of carbon interference problem.

This unit was much too responsive to CO to be usable as an auto exhaust analyzer in its present form, and it is too susceptible to degradation from water intake. It required higher and higher span control adjustments to calibrate, as its exposure to exhaust samples with high water content increased. The unit finally ran out of range capability on the span control and failure in the durability test resulted.

It was judged that this unit would need a more effective water removal system for this specific application, it would require an in-line scrubber for CO and CO_2, and its operation would have to be simplified for the end user.

Test data for IBC N322 W/SC-400 Nitrogen Oxide Analyzer are shown in Tables 7-81 through 7-85.

Photographs of this instrument are shown in Figures 7-52 through 7-57.

Attachment (1)

Table 7-81. DATA COMPOSITE - LABORATORY TEST

INSTRUMENT: IBC N322 W/SC-400

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	9	9	21	8

	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
ZERO DRIFT	LOW	NO	1.0	1.0	0.8	1.0

GAS INTERFERENCE (% of FS) (CYCLE 1)	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	40.0	0	-	0

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO			
				% ERROR ABSOLUTE	% ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	- 3.41	- 1.2		
	LOW	NO	70	+ 1.16	+ 0.8		
	LOW	NO	100	0.0	0.0		
	HIGH	NO	35	0.0	0.0		
	HIGH	NO	70	- 0.26	- 0.2		
	HIGH	NO	100	-	-		
CYCLE 2	LOW	NO	35	- 2.84	- 1.0		
	LOW	NO	70	+ 1.45	+ 1.0		
	LOW	NO	100	+ 0.8	+ 0.8		
	HIGH	NO	35	- 0.06	- 0.02		
	HIGH	NO	70	- 0.52	- 0.4		
	HIGH	NO	100	-	-		

Attachment (1)

Table 7-81. DATA COMPOSITE - LABORATORY TEST (Cont'd)

IBC N322 W/SC-400

CYCLE 3	LOW	NO	35	0.0	0.0		
	LOW	NO	70	+ 0.58	+ 0.4		
	LOW	NO	100	- 0.6	- 0.6		
	HIGH	NO	35	+ 0.06	+ 0.02		
	HIGH	NO	70	+ 0.26	+ 0.2		
	HIGH	NO	100	-	-		
CYCLE 4	LOW	NO	35	- 3.53	- 1.2		
	LOW	NO	70	- 0.58	- 0.4		
	LOW	NO	100	- 1.6	- 1.6		
	HIGH	NO	35	- 1.71	- 0.6		
	HIGH	NO	70	+ 0.52	+ 0.4		
	HIGH	NO	100	-	-		
HIGH ALTITUDE	LOW	NO	35	- 3.41	- 1.20		
	LOW	NO	70	+ 0.29	+ 0.20		
	LOW	NO	100	- 1.20	- 1.20		
	HIGH	NO	35	0.0	0.0		
	HIGH	NO	70	- 0.13	- 0.10		
	HIGH	NO	100	-	-		

	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS) (CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
RESPONSE & RECOVERY	HIGH	NO	3400	12.5	27.0	29.75	16.5

HYDROCARBON RESPONSE	RANGE	INSTRUMENT RESPONSE TO VARIOUS HYDROCARBONS AS ppm 287 ppm ACETYLENE	323 ppm BENZENE	322 ppm ETHYLENE	385 ppm ISOBUTYLENE	337 ppm METHANE	329 ppm TOLUENE
300 Feet Altitude							
6750 Feet Altitude							

Table 7-81. DATA COMPOSITE - LABORATORY TEST (Cont'd)

IBC N322 W/SC-400

VOLTAGE PROFILE	POWER	RANGE	SCALE	READING VARIATION AS FUNCTION OF VARYING LINE VOLTAGE ± 10%	
				+ 10%	- 10%
	115V	HIGH	NO	3445	3450

Table 7-82. DATA COMPOSITE - REPEATABILITY TEST

INSTRUMENT: IBC N322 W/SC-400

WARMUP TIME (Min.)	RANGE	SCALE	(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	9	17	10	14

ZERO DRIFT	RANGE	SCALE	MAXIMUM ZERO DRIFT % FULL SCALE			
			(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	LOW	NO	0	2.0	0.2	0.4

GAS INTERFERENCE (% of FS) CYCLE 1	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0.4	33.0	1.0	-	3.0

GAS INTERFERENCE (% of FS) CYCLE 2	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	36.0	0	-	4.0

GAS INTERFERENCE (% of FS) CYCLE 3	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	36	0	-	0

GAS INTERFERENCE (% of FS) CYCLE 4	RANGE	SCALE	15% CO_2/N_2	1600ppm HC/N_2	10% CO/N_2	3% H_2O/AIR	2000ppm NO/N_2	10% O_2/N_2
	LOW	NO	0	0	0	0.8	-	0

RESPONSE & RECOVERY	RANGE	SCALE	CORRECTED CONCENTRATION	INSTRUMENT RESPONSE TIME (SEC) (AVERAGE OF 2 RUNS)			
				(CYCLE 1)	(CYCLE 2)	(CYCLE 3)	(CYCLE 4)
	HIGH	NO	3400	23.5	8.75	10.5	11

Table 7-82. DATA COMPOSITE - REPEATABILITY TEST (Cont'd)

IBC N322 W/SC-400

ACCURACY DETERMINATION	RANGE	SCALE	COMPARISON CONDITION % FS	NO % ERROR ABSOLUTE	 % ERROR FS	% ERROR ABSOLUTE	% ERROR FS
CYCLE 1	LOW	NO	35	+2.27	+0.80		
	LOW	NO	70	-0.58	-0.40		
	LOW	NO	100	-2.20	-2.20		
	MEDIUM	NO	35	+1.45	+0.50		
	MEDIUM	NO	70	+1.29	+1.0		
	MEDIUM	NO	100	+2.06	+2.0		
CYCLE 2	LOW	NO	35	-4.55	-1.60		
	LOW	NO	70	-1.74	-1.20		
	LOW	NO	100	-0.50	-0.60		
	MEDIUM	NO	35	-1.16	-0.40		
	MEDIUM	NO	70	-0.39	-0.30		
	MEDIUM	NO	100	+2.06	+2.0		
CYCLE 3	LOW	NO	35	+3.41	-1.20		
	LOW	NO	70	-0.87	-0.60		
	LOW	NO	100	-3.19	-3.20		
	MEDIUM	NO	35	+3.20	+1.10		
	MEDIUM	NO	70	+4.88	+3.80		
	MEDIUM	NO	100	+1.55	+1.50		
CYCLE 4	LOW	NO	35	-7.39	-1.40		
	LOW	NO	70	+0.58	+0.40		
	LOW	NO	100	-1.60	-1.60		
	MEDIUM	NO	35	-1.16	-0.40		
	MEDIUM	NO	70	+1.54	+1.20		
	MEDIUM	NO	100	+5.16	+5.00		

Table 7-83. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS

IBC N322 W/SC-400

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO	
				% ERROR ABSOLUTE	% ERROR FS
STANDARD MODE CYCLE 1	5000	NO	50	- 1.88	- 0.9
	5000	NO	30	- 7.8	- 2.2
	500	NO	IDLE	+ 53.52	+ 12.62
CYCLE 2	5000	NO	50	+ 3.57	+ 1.62
	5000	NO	30	0	0
	500	NO	IDLE	+120.53	+ 28.42
CYCLE 3	5000	NO	50	+ 3.79	+ 1.68
	5000	NO	30	- 0.44	- 0.12
	500	NO	IDLE	+ 23.03	+ 5.84
CYCLE 4	5000	NO	50	+ 3.07	+ 1.46
	5000	NO	30	+ 1.79	+ 0.5
	500	NO	IDLE	+ 39.95	+ 9.42
LEAN MODE CYCLE 1	5000	NO	50	- 2.54	- 1.16
	5000	NO	30	- 8.77	- 2.5
	500	NO	IDLE	- 1.42	- 0.36
CYCLE 2	5000	NO	50	+ 5.62	+ 2.5
	5000	NO	30	+ 3.24	+ 0.88
	500	NO	IDLE	+ 0.97	+ 0.24
CYCLE 3	5000	NO	50	+ 4.31	+ 1.92
	5000	NO	30	- 0.22	- 0.06
	500	NO	IDLE	27.91	- 6.58
CYCLE 4	5000	NO	50	+ 3.98	+ 1.8
	5000	NO	30	+ 1.3	+ 0.36
	500	NO	IDLE	+ 43.18	+ 11.46

Table 7-83. VEHICLE TEST ACCURACY DETERMINATION - EXHAUST GAS (Cont'd)

IBC N322 W/SC-400

KEY MODE CYCLE #	RANGE PPM	SCALE	SPEED	NO	
				% ERROR ABSOLUTE	% ERROR FS
RICH MODE CYCLE 1	5000	NO	50	+ 3.98	+ 1.8
	5000	NO	30	- 1.27	- 0.36
	500	NO	IDLE	+222.31	+ 52.42
CYCLE 2	5000	NO	50	+ 3.98	+ 1.8
	5000	NO	30	+ 2.41	+ 0.66
	1000	NO	IDLE	+334.78	+ 77.0
CYCLE 3	5000	NO	50	+ 5.0	+ 2.24
	5000	NO	30	+ 2.64	+ 0.72
	1000	NO	IDLE	+391.94	+ 92.42
CYCLE 4	5000	NO	50	+ 51.12	+ 23.34
	5000	NO	30	- 3.04	- 0.84
	1000	NO	IDLE	+607.81	+ 53.67

Table 7-84. DIAGNOSTIC TEST

IRC N322 W/SC-400

TEST	RANGE	SCALE	PPM NO, PPM HC, % CO		HC/CO/NO	
			TEST INSTRUMENT	EPA BENCH	% ABSOLUTE ERROR	% ERROR FS
SPARKPLUG SHORTED	500	NO	295	147	+100.68	+ 29.6
NORMAL IDLE	500	NO	310	147	+110.88	+ 32.6
IGNITION ADVANCE	500	NO	262	132	+ 98.48	+ 26.00
IGNITION RETARD	500	NO	224	132	+ 69.7	+ 18.4

Table 7-85. DURABILITY TEST DATA

INSTRUMENT: IBC N322 W/SC-400

INSTRUMENT TIME TO FAILURE AND GAS EXPOSURE	
TIME TO FAILURE (HRS.)	176
HC EXPOSURE (PPM-HRS.)	183,040
CO EXPOSURE (%-HRS.)	373
NO EXPOSURE (PPM-HRS.)	18,832
INSTRUMENT STABILITY	
TOTAL NO. DAYS SHOCK TEST FAILURE (3% Variation) 1 or More of 4 Modes	NOT APPLICABLE
SHOCK TEST FAILURE RATE (Failure/Day %)	NOT APPLICABLE
INCIDENCE OF FAILURE IN EACH MODE	NOT APPLICABLE
HC ZERO	
HC SPAN	
CO ZERO	
CO SPAN	
AVERAGE DAILY SPAN DRIFT	
HC%	--
CO%	--
NO%	17.68
INSTRUMENT SERVICE REQUIREMENTS	
A CHANGE FILTER	
TOTAL	--
PER 100 HRS.	--
B DRAIN HOSE	
TOTAL	--
PER 100 HRS.	--
C REZERO	
TOTAL	1
PER 100 HRS.	0.57
D. SAMPLING SYSTEM	
TOTAL	--
PER 100 HRS.	--
E. OTHER	
TOTAL	--
PER 100 HRS.	--

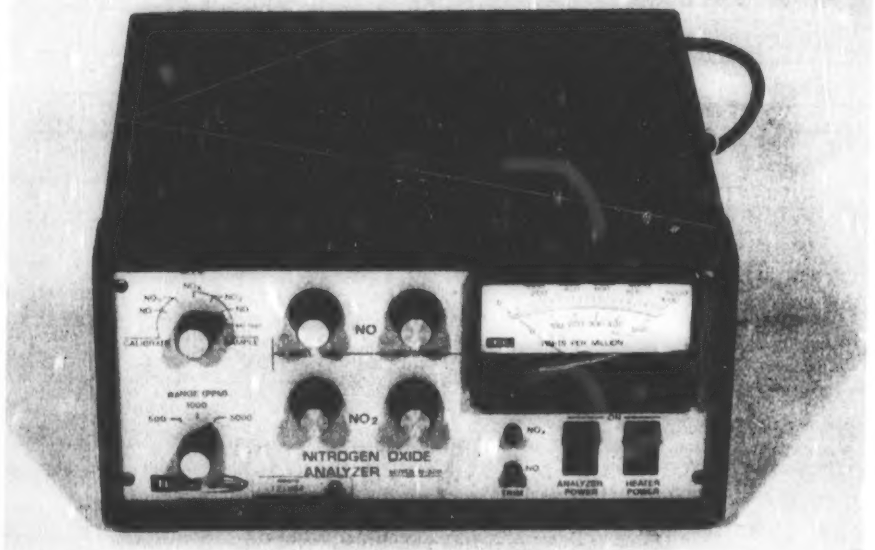
CALIBRATE
SAMPLE
RANGE (PPM)
1000
500
5000
NO
NO₂
NITROGEN OXIDE
ANALYZER
PARTS PER MILLION
ON
TRIM
ANALYZER POWER
HEATER POWER

Figure 7-52. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER

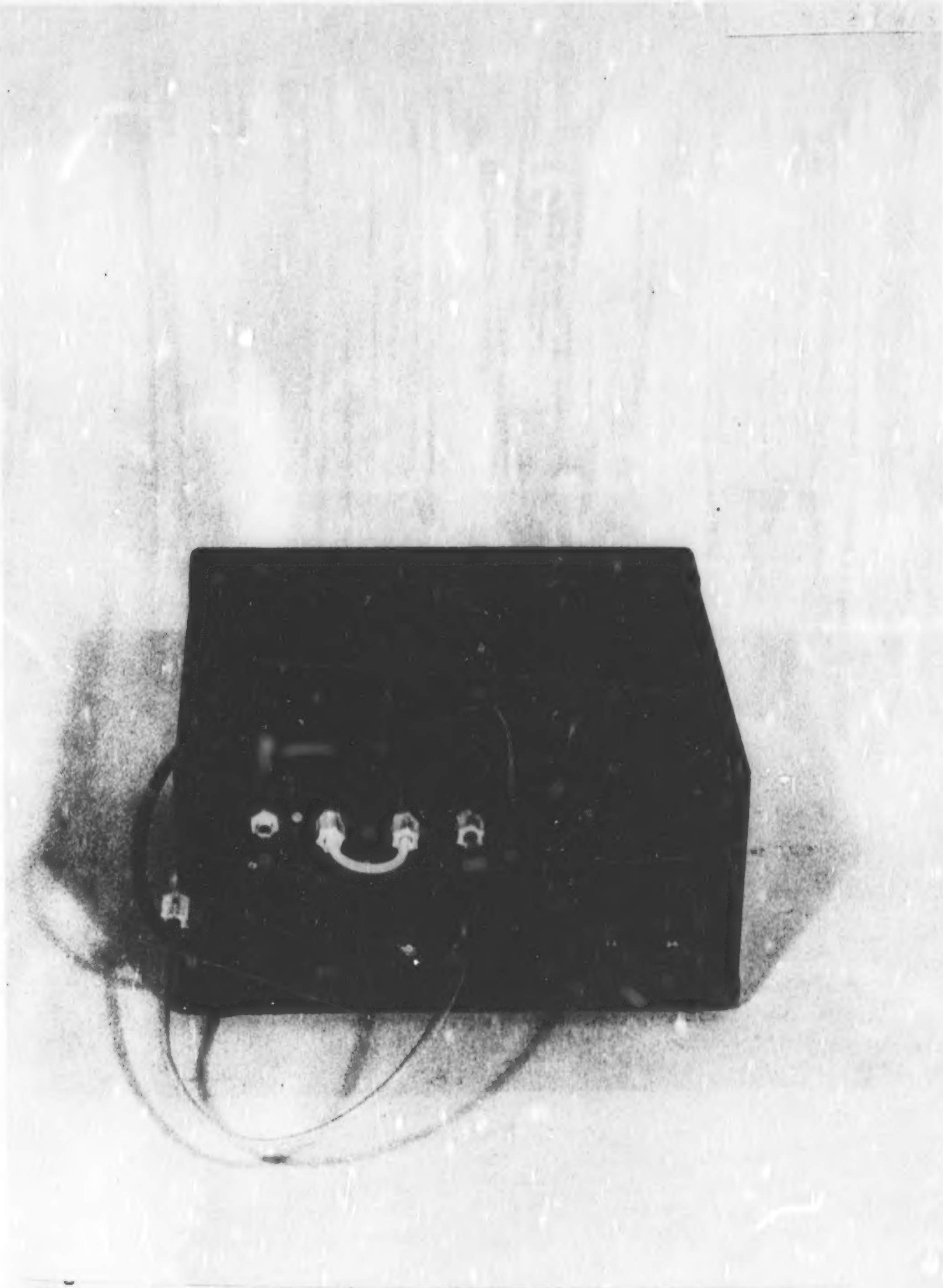

Figure 7-53. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER (BACK)

Figure 7-54. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER (LEFT SIDE)

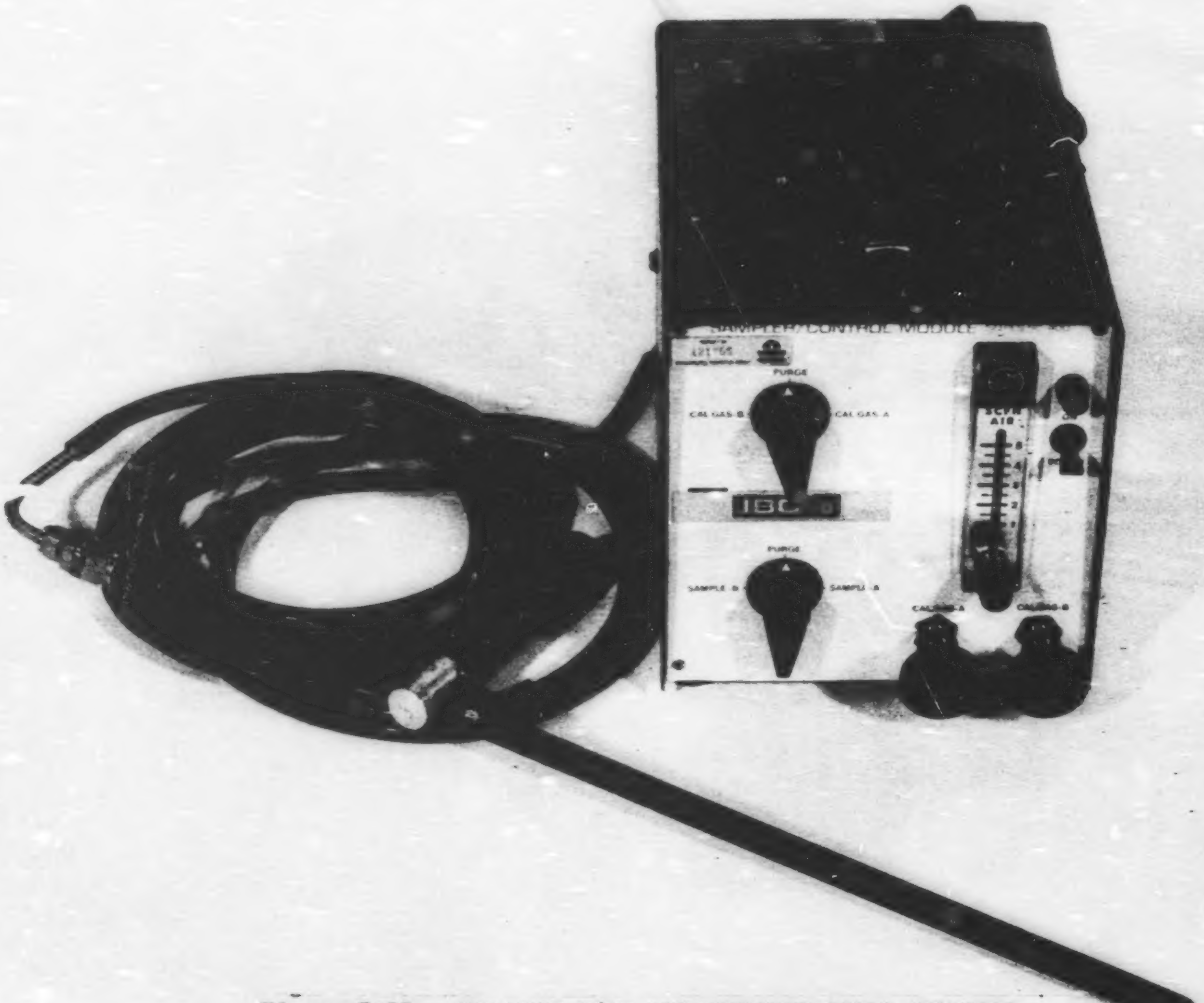
SAMPLER/CONTROL MODULE
PURGE
CAL GAS-B
CAL GAS-A
IBC
PURGE
SAMPLE-B
SAMPLE-A
SCFH AIR
CAL GAS-A
CAL GAS-B

Figure 7-55. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER - SAMPLER CONTROL MODULE

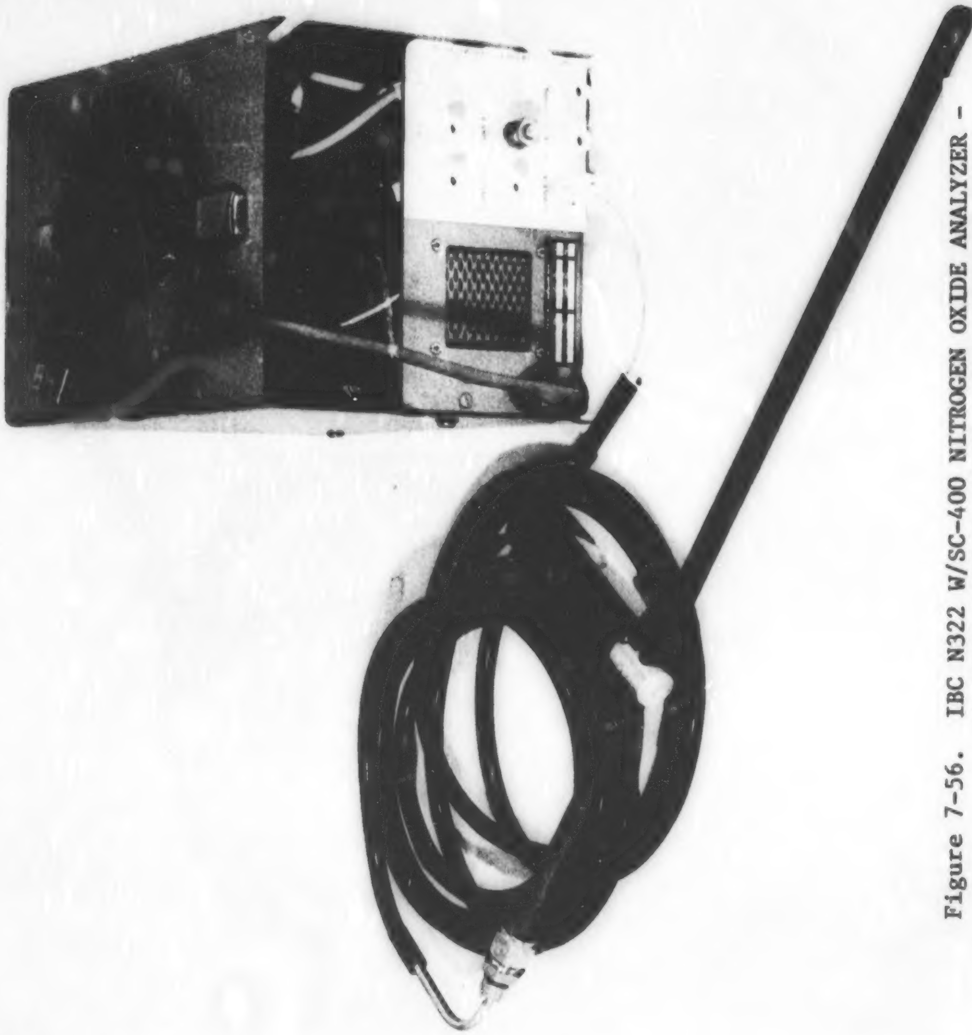

Figure 7-56. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER - SAMPLER CONTROL MODULE (BACK AND PROBE)

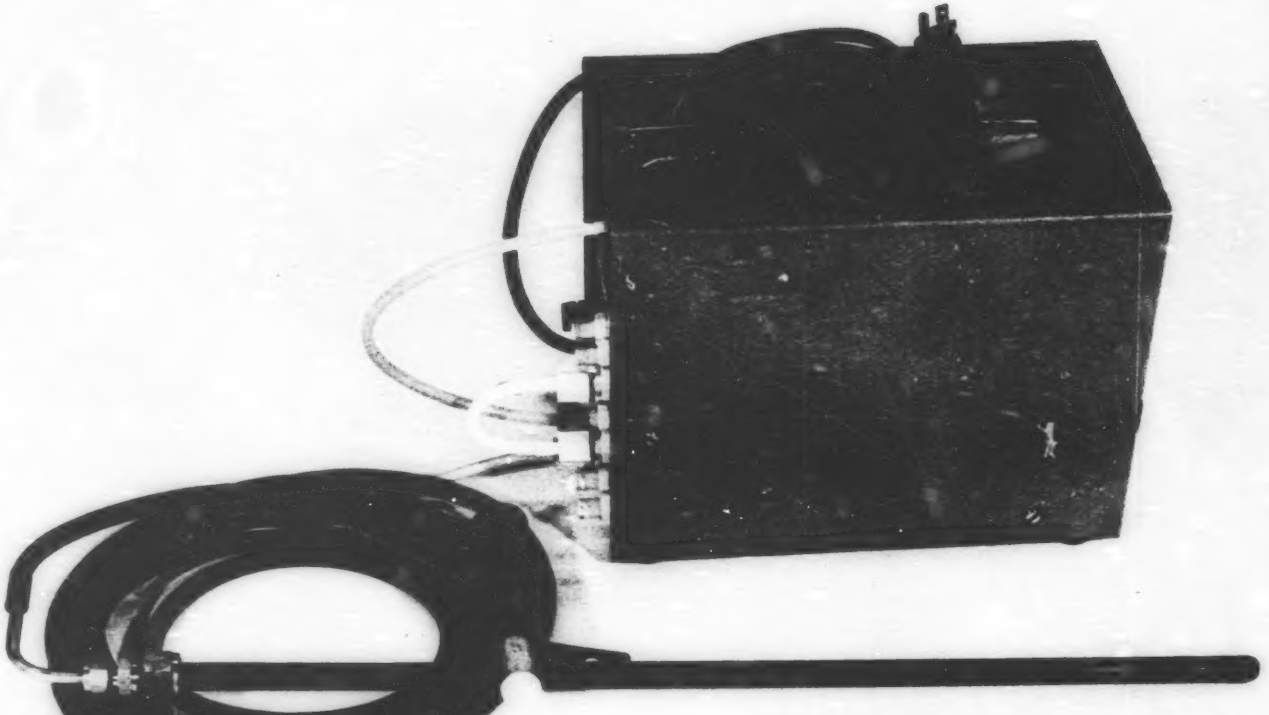

Figure 7-57. IBC N322 W/SC-400 NITROGEN OXIDE ANALYZER - SAMPLER CONTROL MODULE (RIGHT SIDE AND PROBE)